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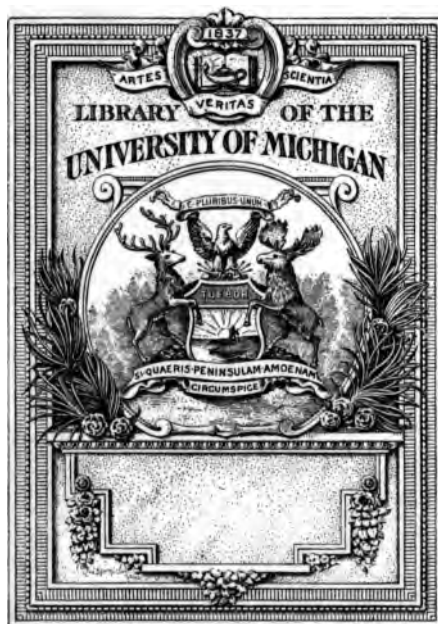
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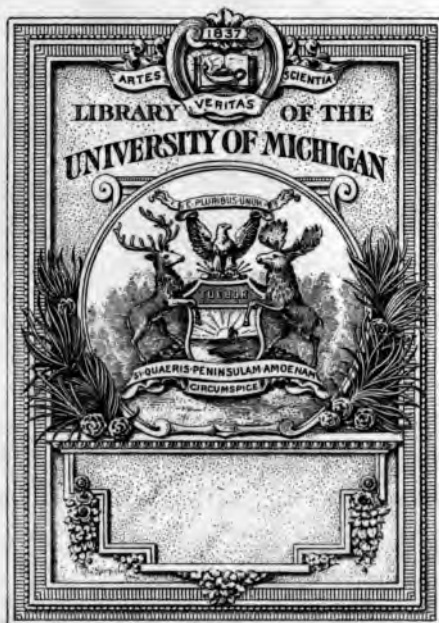
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LETTERS TO A PAINTER

LETTERS TO A PAINTER ON
THE THEORY AND PRAC-
TICE OF PAINTING

BY
W. OSTWALD

AUTHORIZED TRANSLATION BY

H. W. MORSE



GINN & COMPANY

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NOTE

These letters appeared during the winter and spring of 1903-1904 in the scientific supplement of the *Münchener Allgemeine Zeitung*. They brought me at that time many letters, — inquiring, criticising, agreeing, suggesting; and from these letters in part came the idea of this expansion into book form. It is my earnest hope that further coöperation of the same kind may come to me, especially from the ranks of professional artists, that I may learn to improve and complete my explanations in case another edition is called for.

Of course I know perfectly well that my criticisms of views which have become venerable by age cannot fail to bring out objections to this book; but I am not alone in my dissatisfaction with the present antiquarian and “philosophical” methods which are applied to the scientific side of art. Nor am I alone in my desire to see these methods replaced by the only one which has

ever yielded permanent results,—the empirical-experimental method. If this can, for the time being, merely aid in freeing us from a narrow overestimation of the achievements of certain art periods, the advance which will be made toward a true and genuine development in art will be incalculable.

W. OSTWALD

LEIPZIG, March, 1904

The present English edition contains many additions to the German edition of 1904, and has been carefully revised and corrected.

CAMBRIDGE, March, 1906

W. OSTWALD
H. W. MORSE

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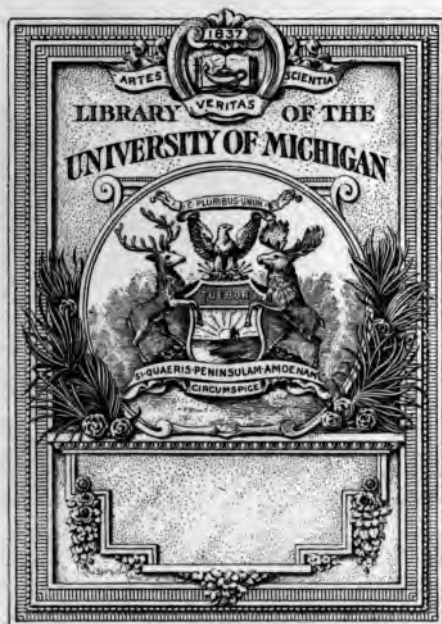
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LETTERS TO A PAINTER

fear by calling attention to the fact that it is under any circumstances an advantage for the working artist to examine for once in the light of science the things he is accustomed to do in his daily work, however modest the rôle of science may be. This is all true enough, and that is just what science is for,—to make practical things easier by letting us know what is important and what unimportant. Another objection which I have heard occasionally in artistic circles I wish to answer at this point. This is the fear that scientific explanation may restrict artistic inspiration and make it weak and insipid. Remember that we are considering the technical side of the matter only, and there seems not the slightest doubt that the creative power of the artist becomes ever freer as he becomes more and more the master of his tools. Experience confirms this. Look through one of the many publications which tell of the way Böcklin worked, and you will read everywhere of the tireless practice and investigation which this great imaginative artist used in the purely technical part of his art. It has become a certainty, to me at least, that the creative color-imagination of this artist was often aroused by this careful attention to the materials

of his art. So I hope you will not object to the "self-evident" parts of what follows.

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The various processes of painting do not differ so much in the nature of the pigments used as in the character of the medium which binds the pigment (which is usually a solid in powder form) to the substratum. The pigments are the same in all the processes of painting, however different they may look in the finished work, and only the binding medium is different. On the medium alone depends, therefore, on the one hand, the special technique of applying the pigment and the subsequent treatment, and, on the other hand, the effect of the color on the eye and the durability of the finished picture. We shall therefore, in what follows, have especially to examine media.

To begin with, all *drawings*, in the narrower sense of the word, are made without the use of any chemical medium. They are produced by putting in the desired lines and surfaces with sticks or crayons of pigment. All transitions between the color of the ground and that of the pigment can be brought out by lighter and stronger strokes of the crayon and by a single or repeated treatment of the surface. In order that such a process may

be carried out the ground must be rough. Its irregularities act like a file on the crayon, taking off its material in the form of powder, which remains lying on the places over which the crayon has passed. Whether or not a really stable drawing is produced in this way depends on the fineness of the colored powder which the ground takes from the crayon. If this is very fine, each little particle finds a resting place in the roughness of the ground and is not easily disturbed by shaking, tapping, or even touching the drawing. Graphite, of which ordinary lead pencils are made, acts in this way; but since the grains simply lie freely in crannies of the ground and are not held fast by any binding material, they can be removed from their position by strong or repeated mechanical disturbances. Lead-pencil drawings are therefore subject to smudging and lead-pencil lines can, for the same reason, be removed with a rubber eraser. Soft erasers (those of dark color) act because of their somewhat adhesive properties, by virtue of which they pick the grains of color out of their resting places. The harder sorts contain, in addition, a sharp powder which grinds away the ground on which the drawing is made and so removes the grains of

color together with a part of their surroundings. If a drawing of this kind is to be kept from smudging, each grain must be fastened in some way to the spot where it lies, and this is done by flowing or spraying with a gummy substance. Only a very small amount of this needs to be applied (very dilute solutions of one to five per cent), since the amount of pigment which is to be held in place is very small. The coarser the colored powder, the smoother the ground, and the thicker the coat of pigment the greater will be the danger of smudging and the necessity for fixing the drawing. Black or red chalk is much less fine in grain than graphite, and the particles of charcoal are the coarsest of all. This latter substance consists of the carbonized remains of wood cells and is not a powder at all until it is broken up by the filing action of the ground. Paper is almost exclusively the substance used as ground, and it has a double rôle to play in a crayon drawing. It must have, in the first place, a certain degree of roughness; the smoother the surface, the less the amount of powder which it can file off, and the less the chance of the powder being tightly held. Strong strokes can then be produced only by a

correspondingly strong pressure, by which both the filing and the binding actions are increased. It is therefore possible to use the smoothest papers (when other reasons make it desirable) for the finest powder (lead pencil), while papers of increasing roughness must be used for chalk and charcoal.

The other duty of the ground is to serve as carrier for the finished work of art, and for this it should have chemical and mechanical powers of resistance in the highest possible degree. The chemical power of resistance is to be chosen especially with reference to inalterability under the oxidizing action of the oxygen of the air. This is an influence which cannot be excluded except by very special means, and which must therefore always be taken into account, so that in what follows we shall continually refer to it. The pure vegetable fiber (cellulose), of which good paper consists, is extremely durable, as is the glue with which such paper is usually hardened. Proof of this we have everywhere in papers preserved in libraries and archives, many of which are hundreds of years old. But wood pulp, added nowadays to papers of the cheaper sort which are in enormous demand, is unstable, and so much

the more so when it has had but slight chemical treatment. Changes show themselves in the yellow or brownish color which such papers take on in the light (most rapidly, of course, in direct sunlight), and also in a decrease in toughness. Both of these processes, turning yellow and turning brittle, take place without the aid of light, but very much more slowly. The artist who desires the greatest possible durability for his creations must therefore carefully avoid such papers. They can usually be recognized by laying a strip of the paper to be tested half in and half out of a book, like a bookmark, and subjecting the exposed half to the action of direct sunlight. A few hours' time is usually sufficient to show a change in the exposed half of the suspected paper.

A sufficient idea of the mechanical strength of a paper is obtained by tearing it. Sheets which are to be moved about, such for example as are kept in portfolios, are best fastened to a larger sheet of stiff paper, which bears the brunt of all mechanical wear. In order that the backing may be changed if necessary, the sheet should only be fastened to it firmly enough to avoid folds during handling, while permitting of easy removal without damage when this is desirable.

As already stated, any good gum can be used as a fixative. It must be dissolved in some liquid, and so we have here two groups, — aqueous and nonaqueous solutions. The choice of the binding medium depends in some degree on the choice of the solvent, for all media are not equally soluble in all liquids.

Aqueous fixatives are the cheapest, and the best fixing substance, as far as durability and unchangeability are concerned, is colorless gelatin, which can be used in one per cent or two per cent solution. It must be applied warm because the solution *sets* in the cold. Gum arabic is equally good. An excellent fixative (a specially prepared solution of casein) is described in the letter on pastel. All paper expands when it is moistened with water, and remains lumpy and uneven when it is carelessly dried; but when it is fastened at the edges — stretched — it becomes smooth again on drying. Unstretched paper dries smoothly if it is hung up by one corner when wet and allowed to dry in this condition. It rolls itself up, to be sure, but can be easily spread straight again.

A remarkable peculiarity of water is its tendency to form drops, due to its great surface

tension. It has this property in greater degree than any other liquid, and aqueous fixatives have in consequence a tendency to form drops on the picture. These cover themselves with color and then run down over the surface, sometimes depositing color at the wrong place.

The way to avoid this difficulty is to decrease the surface tension as far as possible, which can be easily done by adding alcohol (ten to thirty per cent). Ether, soap, ox gall, and other substances act in the same manner, but are not so good. An aqueous fixative containing one of these substances wets the picture evenly and at the same time penetrates more or less deeply, so that the desired result is attained.

Similar results are obtained by the use of certain well-known, traditional fixatives, such as coffee (*au lait*), stale beer, and the like. Such mixtures should on no account be used, for they contain superfluous substances which might easily give rise to undesirable changes, such as yellowness or stickiness.

Nonaqueous fixatives (varnishes) have the advantage of not causing the paper to expand, so that it can be dried after fixing without any special care. They should therefore be used where

leaves cannot be hung up to dry, as in drawings in sketchbooks.

Among nonaqueous solvents alcohol is the cheapest and most convenient. Owing to its small surface tension, it wets the surface easily and penetrates into the interior of the paper. The binding substance which has the first rank here is shellac. Either bleached or unbleached shellac may be used (in the latter case the light-colored "white" grade should be chosen), and a one per cent solution is usually quite strong enough. Other solvents beside alcohol scarcely need consideration, for they have no advantages and have often great disadvantages in the way of inflammability, odor, expense, etc. In countries where pure alcohol is expensive methylated spirit can be substituted.

The fixative can be applied by *flowing* only in the case of such pictures as hold firmly to the paper, so that particles are not washed away by the action of the liquid. In all other cases the fixative must be applied in the form of a very fine spray of innumerable minute drops. For this an atomizer or sprayer of glass or metal, which can be obtained at the shops, is useful. The most convenient are metal ones in the form

of a pump, which is fastened to the bottle containing the fixative. The fine opening must be kept clean or it will soon get stopped up. To avoid this, pure alcohol (or water, if it is an aqueous fixative) should be blown through the apparatus after use, or a few drops of the pure solvent may be allowed to flow *in* through the opening.

A fixing substance has in general no influence on the durability of the picture, since it is present in such small amount. Even when the binding substance loses its fixing properties with time, owing to decomposition, the worst that can happen is the restoration of the original condition of the picture before it was fixed. The only danger to be avoided is a possible coloring of the paper by the products of decomposition of the fixing material, and when pure gelatin, casein, mucilage, or shellac is used no such danger exists.

Under no circumstances should more fixing material be used than is necessary to hold the particles of color firmly. The necessary amount depends on the materials used and can easily be determined after a few trials. After fixing is complete the picture should show no effect on being rubbed with the finger, and this serves as a test.

II

MY DEAR SIR :

You write: "It has given me a great deal of pleasure to see the different relations which we had previously discussed from various sides brought together in this inclusive way. A question has occurred to me which I think I have already asked you once, but the explanation of which I have forgotten. Why are lead-pencil marks glossy, while lines made with chalk or charcoal do not show this effect?"

I answer this question very gladly, especially because it touches a point which we shall continually have to take into consideration: this is the differentiation of the two kinds of light which we receive from a picture.

In order that you may understand this whole matter thoroughly, let me ask you to take a piece of colored glass in your hand and try with it the experiment I am going to describe. If you turn toward the window and hold the piece of colored glass horizontally, just below the level of the eyes and a little way off, you will find that

it acts very much like a mirror. You see an inverted image of the window and the objects in it, in their own natural colors, and the color of the piece of glass does not show itself at all. Now lift your hand and hold the piece of glass vertically between your eye and the window. You see all the light which comes to you from the window in the color of the glass, and according as objects outside are darker or brighter, or have color like that of the piece of glass or different from it, you will see differences at different points. If your glass is of a very pure color, no other differences will be visible; if it is not very strongly colored, a corresponding amount of the color of individual objects remains.

These simple and well-known phenomena are not "fundamental" in the scientific sense of the word, but they will nevertheless be of the greatest importance in our future considerations. They show us the difference between *surface light* and *body light*. From every surface, including that of a picture, we always get both kinds of light, and the effect produced by any picture depends on the relation between them. It should be remembered that surface light is *colorless*,—that is, it has the color of the general illumination of the

room. Colored light can only be produced in the body lights, and the light which reaches our eyes from the picture is the deeper and the purer the more the body light outweighs the surface light. When you held the colored glass between your eyes and the window no surface light could be seen, for the surface exposed to the light of the window was turned away from you, and you produced the deepest and purest color possible with that particular piece of glass. It is of course possible to produce mixtures of surface and body light, but we will leave the discussion of that point for a later time when we shall need these facts in order to clearly understand some of the other phenomena of the technique of painting.

Let us turn our attention for the time being to the problem of the lead-pencil marks. The graphite of the pencil may be seen by microscopic examination to consist of scales with smooth (and therefore reflecting) surfaces. When the lines are drawn the particles are laid down parallel with the surface of the paper, like the scales of a fish, forming a smooth surface, which reflects a great deal of surface light when held in certain positions and which is therefore glossy. The particles of black chalk and charcoal are, however,

wholly irregular fragments, which do not form a smooth surface and are therefore not glossy.

You also mention in your letter that lead-pencil drawings show much less gloss after being fixed. The paper swells during fixing; the individual fibers move and take up other positions, moving the particles of graphite from their regular parallel arrangement, and the result is a corresponding decrease in the surface reflection. It follows directly that chalk and charcoal drawings show no change in appearance on being fixed, for here there is no parallel arrangement of particles to disturb.

We are now better prepared to expand our considerations to include the forms of technique which are directly connected with monochrome drawing, — drawing with colored crayons and pastel. Drawing with colored crayons can be carried out in many ways. Closely connected with the process just described comes a technical method which may be called after its most celebrated representative, the *Lenbach Method*. This consists in enlivening a drawing made in dark crayon by adding individual colors. These colors can be laid on with colored crayons (pastels), but it is possible also to take up the color

simply as fine powder with brush or blender, and so apply it, working it into the irregularities of the paper with the finger or some other tool. This latter process is applicable where large surfaces without sharp contours are to be treated, while the use of crayons makes finer drawing possible.

There is nothing more to be said about the technical side of this process, since it depends on the same principles as those of simple drawing. The same is to be said of its durability: if the picture is protected against mechanical injury (rubbing, scratching, erasing), its life depends only upon the durability of the pigments and the ground. With graphite, red chalk, white chalk, or charcoal, there is no question as to the durability of the color, and pictures made with them last as long as the substance on which they are laid. We shall discuss the durability of other pigments later.

Pastel, in the narrower sense, differs from drawing in that the color scheme of the picture is not limited to the color of the background and the color of the crayon, but has freedom in all directions. This demands that the ground shall be more or less completely covered with color.

Transitions appear here as they do everywhere. Sometimes the color of the ground is made use of, only the most important parts of the picture being finished in color, and this method is much in use for portrait work. Sometimes the entire surface is covered with color, and the result aimed at is to reproduce the optical peculiarities of the subject as perfectly as possible, as in working with oils. In this case the color of the ground has only secondary influence, and it should not appear anywhere in the picture, except perhaps to gleam through here and there as an aid in the production of a special effect. As far as fixing is concerned, it is always better to cover the ground completely, because pictures treated in this way show the least change on being fixed.

The basis for the preparation of colored pastels is chalk, which is mixed with various pigments and then formed into rods or crayons with the aid of an aqueous binding medium (gum tragacanth). This binding medium serves only to give the necessary coherence and hardness to the pastels and has nothing to do with the taking of the color on the surface. This is primarily a mechanical matter, which takes place as described above, the rough ground taking off color from

the crayon in the form of powder, which remains fast in the irregularities of the paper.

In the matter of the complete covering of the ground there appears in the case of pastels a difficulty which is hardly of importance in drawing. In order to produce a sufficient covering effect, the layer of colored powder must have a considerable thickness, and not only must the hollows of the ground be filled, but even the raised points must have their layer of powder.

It is, furthermore, very often necessary to cover with another color one which has been already laid on. This point is attained first of all by the use of very soft pastels, made by adding to the powder just enough of the binding medium to prevent crumbling. A further necessity is a ground which can take a heavy coat of color and which holds it firmly. Here one can use either a very soft, pulpy surface which takes up a great deal of color, or a hard, rough surface which has a strong filing action on the crayons. The choice and preparation of an appropriate ground for work in pastel depends on these two properties, and as one or the other of them is foremost, corresponding distinct differences in technique are required. A picture made with pastels having these

characteristics is certainly very sensitive to mechanical injury, — the promenade of a fly across the surface may do damage, — but it may have a very long life if it is protected by careful fixation and framed behind glass. This is shown by the pastels in the Dresden Gallery, some of which are hundreds of years old. Even the oldest pastels show none of that brown "gallery tone" which develops on nearly all oil paintings, and their freshness of color seems wholly unimpaired by time. This is because these pictures consist of pure pigments *without medium*. The stability which belongs to the pigments by themselves or in mixtures belongs also, of course, to the pastel picture, and the many changes which take place in the course of time in the media of tempera and especially of oil paintings are entirely excluded.

These changes are the cause of the slow disintegration of such works, and in the case of pastel chemical reactions between color and medium, or mechanical changes due to flaking, cracking, and peeling, are impossible.

Then, too, the mass of color in pastel has a certain thickness, and the effect of each individual color in different parts of the picture is produced by the presence of a comparatively large amount

of coloring substance. Even though a slow disintegration (for example, by the oxygen of the air) may take place, a very much longer time must elapse before the disappearance of color becomes visible in a pastel than in the case of a water color, where the color effect depends upon an extremely thin layer spread as a transparent film over the white ground. It must, however, be remembered that a pastel color is exposed to the attack of the oxygen of the air from all sides because of its powdery nature, so that if a color is affected by the air its destruction will be comparatively rapid. This can be very clearly seen in pastels made of substances which are sensitive to light, such as Carmine and many artificial aniline colors, which are to be found only too frequently in the shops. There is a quite sufficient choice of pigments of well-proven stability, and one should exclude the others absolutely (except for the most transient sort of work) and subject them to the strictest tests in case of doubt. You will find something about the method of testing colors in a later letter.

Precipitated chalk is the substance which is added to the pastels, in quantity increasing with the lightness of the color value desired, and it is

not at all subject to suspicion from the chemical standpoint. Since it occurs naturally, there can be no doubt about its stability, and its composition (calcium carbonate) makes any special chemical influence on the colors improbable. Chalk is especially inactive toward the inorganic colors (the oxides of iron, manganese, copper, chromium, etc., and ultramarine, cobalt, the chromates, etc.). Its action on Prussian Blue (the ferrocyanide of iron) might perhaps be undesirable, since this is decomposed by basic substances with the production of a yellow color (due to the separation of iron oxide, with the formation of another ferrocyanide), and since calcium carbonate easily becomes basic, with the loss of carbonic acid. The conditions for this reaction are, however, not present either in the preparation of the pastels or in the conditions under which pictures are kept, so that Prussian Blue may be regarded as a stable color for pastel work. If all these facts are taken into account, a somewhat surprising conclusion is reached,—that pictures done in pastel, when they are protected against mechanical injury by glass, are about the most stable products of the painter's art.

III

MY DEAR SIR:

The opinion which you express in your last letter, that pastel painting is not of much use for real, serious work but only for frivolous things, has hurt my feelings. For my own part, I consider it the most beautiful and expressive of all the methods of painting. There are, in fact, but few problems which cannot be solved by pastel, and it offers the artist a freedom which is not approached by any other technical process. I mean by this that the artist is in no other process so independent of his materials, so free to make extensive changes in his half-finished picture, so free to interrupt his work at will, while his results are at the same time most durable. In brief, if it were not impossible to produce a *transparent glaze* of color in pastel, I should not hesitate to pronounce it the most perfect of all processes. And even this failing is not so important since painters have learned to pay attention to the almost universally present effect of *atmosphere*; the effects which can only be produced

by transparent glazes are rarely necessary, and a cloudy glaze is very easily produced in pastel.

You add that the selection of pastels which can be had in the shops is so poor as to practically exclude its use in landscape work. I am quite ready to admit this, and hope you will be interested in a detailed explanation of my own experiences in pastel.

The pastels of the shops are especially objectionable on account of the unreliability of the pigments used in making them. The short-lived aniline colors are used in a large measure, and the artist who considers the durability of his works will therefore do well to make his own pastels from the raw pigments, which are used by every calciminer and plasterer.

This is a pleasant and easy occupation, which I began when I wanted blue grays and green grays for my landscapes. Before very long I found myself making my whole supply, for the process is a very simple one.

You need, to begin with, a mortar twelve or fifteen centimeters in diameter, and a supply of ordinary white precipitated chalk. Pour half a liter of water on ten grams of gum tragacanth, and set this in a warm place. The next morning

you will find it a gelatinous mass, which is to serve as the binding substance. To prevent it from spoiling, a little β -naphthol (from the drug store) should be added. Label it "Solution A."

Most of the pastels which one needs contain a good deal of chalk, and this gum A is too strong to be used in making them, so a portion of it should be diluted with one part of water and another portion with three parts of water, and we will call the first (the one with one part of water) B, and the other one C.

The undiluted mass A will be found just right for the metallic pigments, — Chrome Yellow, Chrome Red, Green Cinnabar, and the like. The ochers need solution C or a still more dilute one, as does also Ivory Black. But colors sold under the same name are often quite different, and a few preliminary trials with the different solutions will usually be necessary before a mass of the desired hardness or softness is produced.

It is a good plan to make some white pastels first as an introduction. Take about fifty grams of chalk weighed out roughly on the letter scale. Put it in the mortar and add thirteen to fifteen cubic centimeters of the dilute gum solution C, rubbing up the mass with the pestle until it has

about the consistency of putty. If the mass is so thin that it runs, add more chalk; if too thick, add a little water. In a short time a homogeneous mass is produced, which must be formed into sticks. This may be done by rolling with the hand on a layer of newspaper or blotting paper, but better looking pastels are produced by pressing the mass out of a sort of syringe with a nozzle a little larger than a lead pencil. My own syringe is made from a discarded bicycle pump, and I have made thousands of crayons with it. The "sausages" so produced are allowed to dry, preferably in a warm place, and they are then broken into pieces the length of the finger.

Let us next try a set of gradations of a color, — Ultramarine, for example. For this purpose a larger amount of the white chalk mass is first prepared, to be used as a stock. Then take fifty grams of Ultramarine and, using the medium strong gum B, make the mass for the darkest pastels. When these are finished, make the same amount of the same mass, remove it from the mortar, and divide it into two parts. One half goes back into the mortar, an equal amount of the white stock is added, and the two are worked up until all spots and stripes have disappeared. This

takes only a few minutes, and the pastels formed from this mass have the second and lighter value.

The remaining pure Ultramarine mass is again divided, and to half of it is added enough of the white mass to make up the same total quantity as was used before. This time the Ultramarine forms a quarter, and the white chalk three quarters, of the whole. This is mixed and formed into the third value. And so it goes on; half of the remaining Ultramarine is each time made up to fifty grams by adding chalk. Between the seventh and the tenth steps the hue of the mass will become so light that further dilution produces no noticeable difference, and the series is finished.

The pigment and the chalk can, of course, be weighed out in dry form in the proportions given and the binding substance added. The latter must, under these conditions, be made up with regard to the proportion between pigment and chalk. For example, the first shade of Ultramarine must be mixed with one half B and one half C, the second with one quarter B and three quarters C. The remaining mixtures, composed largely of chalk, can then be made up wholly with C, since the small error is not of importance. I have found the first method by far the most convenient.

It is important that the gradations in pigment should be made in just this way, so that each subsequent mixture contains the *same fraction* of the amount of color as the previous one. This is an expression of a general law: The eye (and other sense organs as well) perceives not equal *differences* but equal *ratios* as corresponding gradations, and you will find that as a matter of fact the gradations of brightness or saturation in such a series appear equally spaced.

The process is the same with all the colors which are to be used, and a fine series of pastels is easily produced in a short time. The whole process is so easy that it will soon be found convenient to treat various mixtures — Ultramarine with black, for example — in the same way as the pure pigments. Here the personal necessities of the artist immediately suggest the direction in which new experiments are to be made. It is well to keep in mind the rule that the color will have the same effect in the finished picture as in the *dry* mixture of colored powder. The moisture of the binding material produces a darkening in value which disappears on drying and needs no consideration.

The actual process of painting with such pastels is affected very strongly by the paper used. The usual application of pastels to light, sketchy work brings no especial demand with it, but when a painting of full artistic effect is to be made it is necessary to choose a paper which will hold a heavy coat of pigment. For such work I have found nothing better in the market than a paper with pyramid grain (No. 3) made by Schüffelen in Heilbronn. If this paper is not to be had, one must turn to the ordinary gray board with a rough surface which has not been made glossy by calendering. It is not hard to find a good board, and it is improved by wetting it with water and hanging it up by one corner to dry. This makes the surface rougher. There is also a kind of paper which is covered with fine linen or cotton, used to give strength to maps, plans, and designs for machinery, and the cloth side of this is very well adapted to pastel. It is of course easy to prepare by fastening fine cotton, linen, or silk cloth to a strong, smooth paper with starch paste, never with glue or mucilage.

On this ground the color is worked in lavishly in broad masses, without the slightest thought of economy, using the broad side of the crayon for

the large surfaces. Soft gradations are easily produced by roughly overlapping the colors and subsequent blending with the finger, which can be protected by a rubber cot. For harder effects the blending is omitted. After the large surfaces have been put in the details are to be added.

The color is removed from any place without difficulty by means of a dry bristle brush of the right size, and the colors which are then put in take just as they do on the clean paper. In the same way one can remove entire portions of the picture which have not been successful. In order to give an idea of the freedom one has, let me mention that, not very long ago, I made a picture on a piece of paper which had originally served some lady visitors of mine as ground for their first attempts at pastel, and on which my little son had afterward expressed in writing his opinion of their achievements. Whatever the judgment on this picture may be in other respects, there is no trace to be seen of the previous mistreatment it received.

The principal objection to this beautiful mode of expression is the fixing. It must be admitted that any fixative produces some change in the picture, making it a little darker and at the same

time harder. It must, however, be remembered that there is no technique of painting which does not show differences in the appearance of the colors during their application and after the picture is finished, so that this is not exclusively a defect of pastel. It is, however, so easy to produce gradations in this work that there is danger of an excess of softness, so this natural hardening after fixing may after all be no disadvantage. I have made a great many experiments on fixatives and expect to continue them, but for the time being I will only tell you about the one which, so far, seems the best.

Place fifteen grams of commercial casein in a large glass and cover with a little water; then add solution of caustic potash (potassium hydroxide) a drop at a time until the casein dissolves to a somewhat muddy mass. An excess of the caustic potash must be avoided. It is therefore best to add a little casein until some remains undissolved. Now add two hundred and fifty cubic centimeters of alcohol, or, if you do not object to the odor, wood alcohol can be substituted. The fixative is then ready, but it is best to let it settle and decant the clear liquid for use, or else to separate the residue by filtration to avoid the chance of stopping

*and make up the
whole with water to a total
volume of one liter.*

up the atomizer. A white precipitate usually forms on standing, and the supernatant liquid should be poured off without disturbing it. This is sprayed on the finished picture, and care must be taken that no drops form and flow over the surface. Where there is danger of this the liquid should be removed with blotting paper. When it is uni-

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picture, and an expert misses something of the dry glossy gloss of untreated pastel. But there is not the least difficulty in working on the dry picture without further preparation, and the character of the untreated painting can be restored with very little labor by going over the surface with the same

Page 30, fourth line from bottom of page
"substituted," "and make up the balance of the
volume of one line."

Letter to a Painter.

crayons as before and filling in the flaws which have appeared. A second or, if necessary, a third fixing holds the newly added pigment tightly, and the finished picture becomes so firm after repeated fixing that it can be wiped or even rubbed with bread without suffering in the least.

If the picture is to be framed, it is perhaps better to leave out the last fixation, especially if the picture is soft and delicate in character. Once behind glass such a pastel is possessed of durability and unchangeability far beyond that of any oil painting, and the beauty and purity of color of such a picture cannot be attained by means of oils. One doubt may be raised: the necessary paper cannot be obtained in sheets larger than sixty-two by ninety-six centimeters, which would therefore be the largest size available for this work. Larger sizes would, however, be manufactured if a demand for them existed, and there is no difficulty in preparing a ground for pastel in any size whatever by the method given above (page 28).

Summing up the whole matter, pastel has the following advantages. It is easy to prepare one's own colors with the greatest certainty of having material which is really durable and well adapted to the work. The finished picture does

not darken, scale off, crack, or "become blind," nor has it any other of the innumerable diseases of oil paintings. This process assures to the finished picture, when carefully fixed, the greatest durability attainable by any process known at the present time. One has in pastel the most complete freedom, and the most far-reaching changes in the finished picture may be made without any fear that cracks will appear or the colors previously used show through the later covering, — dangers which must be avoided when working with oils. Any amount of work may be subsequently done on the finished picture without the appearance of differences between the original and the later work, so that one can stop at will and begin work again at any time. On the other hand, there is not the least difficulty in covering surfaces of any size with a uniform tone, since one has only to use the same crayon; and the production of smooth transitions, as, for example, in the sky of landscapes, offers just as little technical difficulty. Since every color comes cleanly from the crayon to the picture, any smudging, such as may occur in other processes from the remains of color in a brush or by stirring up the under painting, is impossible. Since no

medium which dries slower or faster is present, it makes no difference whether a mass of color is laid on at a stroke or at various times. If a particular crayon is marked, it can be used after any length of time without the slightest trace of a break; and, finally, no material is used which has a strong odor or soils the clothing. The dust which is produced while working with pastel can be made harmless by allowing it to gather in a tin or pasteboard trough a few inches wide, fastened beneath the picture; and to prevent dust from gathering on the surface of the picture, the easel should be tilted slightly forward. Of course the fingers get dirty, for one soon lays aside all protections as hindrances to energetic work, but the colors are of such nature that they can be very easily washed off. An occasional rubbing with lanolin prevents the hands from becoming rough under the action of the chalk dust and the frequent washing. But I really must stop, for when I begin to sing the praise of pastel it is hard for me to leave off. Are you now persuaded that pastel can really be taken seriously?

IV

MY DEAR SIR:

You say that you have succeeded without any difficulty in making pastels according to my directions, but that you do not know what pigments to use in order to be sure of really durable results.

I will try to give you an answer which shall be as short and as definite as possible; but this will not end the matter, for the adulteration of pure pigments, by adding to them things which make them cheaper or more brilliant, is a very widespread evil. There is, of course, no protection against unreliable colors, when one orders pigments which are stable and gets adulterated ones instead.

There is fortunately a fairly easy way of recognizing many adulterations, especially those "beautifiers" which consist of coal-tar colors. Most of them are soluble in water or alcohol, while the pigments we want are not. Place some of the pigment which is to be tested for coal-tar derivatives (assuming that you have the raw pigment in

powdered form) on several layers of white blotting or filter paper, piling the color up in a little heap with a hollow top, and drop water into this hollow until it runs through the pigment and into the paper. Then examine the paper, and you will easily recognize a soluble pigment if one is present, for it will be visible not only on the under side of the top sheet but also in the sheets below this. Make the same test with alcohol, and a third with a mixture of alcohol and a little aqua ammonia. If the liquid comes through uncolored in all these tests, you will be fairly safe in concluding that no coal-tar derivatives are present. This conclusion is not an absolutely safe one, since many coal-tar colors, added in the form of insoluble "lakes," do not betray themselves under these conditions; here the chemical expert must decide.

The various ochers are, to begin with, perfectly *fast* pigments. Their colored constituent is either ferric oxide or its hydrate, the former having a red color, while the latter is yellow. The yellow oxide is changed by heating or "burning" into the red one. If the heating has not been very strong, a lively yellowish red (English Red) is produced; if the heating is stronger, a violet-red color (Caput Mortuum) is the result, both being ferric

oxide. The Sienna earths are also ochers which contain iron.

The ochers, and the Sienna earths as well, are not adapted to pastel, since they contain so much clay that crayons made from them, even without any binding material, are too hard for comfortable work. In their stead the pure artificial ferric oxyhydrate and ferric oxide are to be recommended, and they are also very cheap. The first-named usually holds together strongly enough without any binding substance, or can be made firm with a very little gum, while the red ferric oxide will be hard enough if it is made with the dilute solution C. The darker kinds, like Caput Mortuum, require more gum. English Red often contains soluble substances which bind it very firmly together, and it must then be purified by repeated extraction with hot water. The colors which one gets in the various natural ochers can be easily produced by mixing yellow and red ferric oxide, and you will no doubt soon find it convenient to make several series of these pastels.

Ivory Black is used as the black pigment, and is perfectly reliable. The finer grades require very little gum, the coarser ones more, perhaps solution B. From this and the ferric oxides a

number of brown pigments should be made. The yellow oxide in combination with black gives a green gray which is very useful for landscapes. The other blacks (lampblack, etc.) all consist of carbon and are absolutely unchangeable.

Ultramarine is also perfectly reliable, and it should be used with solution B. From it and a black in various proportions you can make three or four series of blue grays, which you will find most useful both for landscape and portrait work. Ultramarine with Caput Mortuum will give you violet grays, which you will find very welcome.

The oxides of chromium are also perfectly reliable. There are two of these, one a dull and one a brilliant pigment, both especially valuable colors. Here you must be on the lookout for fraud, for nowadays the so-called "Green Cinabar" is often sold under the name of "Chrome Green," and its durability is of a far lower grade.

Another fast color is Cobalt Blue (or Thenard's Blue), which is especially well adapted for mixing with red pigments. The so-called "Yellow Ultramarine" (barium chromate) is a sulphur-yellow pigment of great purity of color and perfect reliability, but it is rather pale and finds limited

application. Better in color and equally stable is Strontian Yellow (strontium chromate).

We come next to a series of pigments which are serviceable enough but which, for general reasons, are not to be considered as perfectly durable. I use them myself without question; for the unfavorable circumstances which affect their durability occur so seldom that I take the risk. Then, too, the immortality of my own work is not a matter that lies very near my heart.

In this line Prussian Blue comes first as a very nearly indispensable pigment, and, so far as my own experience goes, it is durable in pastel. The pure pigment is far too strong in color to be formed into sticks, and its mechanical properties are poor. So several times its weight of chalk should be added even for the darkest pastels. The cheaper qualities of Prussian Blue contain a large proportion of such substances already and they should not be used. Buy the dearest kind of strongest color, which will stand mixing with a great deal of chalk. Only a very small amount of binding substance will be necessary (solution C).

Prussian Blue is very frequently used in mixtures. With yellow ferric oxide it gives greens which are excellent for landscape work and which

have great durability. With black it gives a somewhat greenish-blue gray, and with the yellow pigments given below it gives greens of various kinds.

Another valuable blue pigment is Indigo, and I prefer to use the artificial product, which comes in mass form. This gives, with three times its weight of chalk and very little gum, the darkest values, the lighter ones being excellent for distance effects. Mixed with yellows it gives dull greens; with reds it gives very useful violets.

We have no bright red pigment of first-class stability, but there are a number which belong to the second class. Carmine is absolutely untrustworthy, but Madder Lake or Alizarin Lake (which is made from artificial alizarin red) may be safely used. This latter gives a splendid violet with Ultramarine and a fairly good one with Indigo. In the pure state it gives a bluish-rose color when mixed with a large amount of white.

The metallic colors, Cinnabar, Red Lead, and Chrome Red, also belong to the second class. The darker kinds of Cinnabar are the most trustworthy, but there is always danger of their turning gray in bright light. Red Lead is, for pastel, stable in the light, but it darkens rapidly in air

containing hydrogen sulphide. Both colors need a large amount of gum. Chrome Red (basic lead chromate) is a dark, brilliant red, which is, so far as my experience goes, quite fast in pastel. It is probably the most durable of these three, but I should not hesitate to use any of them. It is best in making mixtures to replace them as far as possible by other pigments of undoubted durability.

A very useful pigment is Cadmium Yellow (cadmium sulphide), which is to be had as *pale* and *deep* Cadmium Yellow and as Cadmium Orange. It is not so stable as the colors previously mentioned and becomes gradually paler when it is exposed to light and moisture. It is, however, sufficiently durable, and can be used either in the pure state or mixed with blues and greens (Prussian Blue and chromium oxide). Another fast yellow is Zinc Yellow. With Prussian Blue, it gives very useful bright greens called Zinc Green in the shops.

The yellow lead pigments, such as Chrome Yellow (lead chromate) and Naples Yellow (lead oxychloride) should be avoided in pastel. The dust from them is poisonous and dangerous to health, and they have usually no great stability in bright light, although there are some fast kinds in

the market. Their place is filled advantageously by the yellow pigments mentioned above.

All the horde of greens, sold under the names Green Cinnabar, Chrome Green, Zinc Green, Oil Green, etc., are made from Prussian Blue and the lead and zinc yellows, with the most varied additions in the way of colorless substances. The painter will find it best to prepare these mixtures himself and to use Cadmium Yellow or Strontian Yellow instead of Chrome Yellow, which contains lead. Greens made in this way are quite stable.

We have about reached the end of the list of colors. There are, of course, other durable pigments, but they can usually be dispensed with, replaced, or imitated by mixtures of the colors given, with the same effect. All the pigments given can be mixed in any way whatever without any influence on each other, and since the individual grains of color lie on a pastel painting without coming into very intimate contact, and no medium tends to bring them together, the chemical action of one color on another is excluded in far greater degree than in work with oils.

One other point: you will find it convenient to make dark gradations with Ivory Black as well as the pale ones with chalk. The same method is

used as with the chalk, but three mixtures will usually be found sufficient.

You now have the most important points. If you want a more complete and comprehensive knowledge of pigments, you should turn to the literature on that subject.

Finally, let me give you the general method of testing pigments to be used in pastel, with respect to their stability under the action of light. Cover a piece of pastel paper smoothly with the color in question, using a medium shade. Fix the color and expose it to the light so that half of it is protected. If you possess a photographic printing frame, place the colored strip in it, covering half of it with black paper or a folded piece of pasteboard, the paper lying half in and half out of this covering. If the test is made in summer in bright sunlight, an exposure of a few days will be sufficient to show whether the exposed part has changed its color compared with the part which is protected from the action of the light.

In making such a test you must avoid being deceived by a possible yellowing of the paper, for if this is made of poor material it may show very rapid changes as a result of the action of strong sunlight.

V

MY DEAR SIR:

Your colleague rejoices too soon. It is perfectly true that my last letters contain practical directions and recipes exclusively. I left out the theoretical explanations not because I did not know them but because I want to persuade readers like that gentleman that theoretical knowledge is not a thing which prevents one from working out practical applications. Quite the opposite is true. At any rate, all the directions I have given are based on theoretical considerations, and I have worked out and improved the various points after thinking out the theory in each case. As an indication of this let me state these points again from the *general* point of view.

Let us begin with the fact that pastel colors have good *covering* properties. This means that a coat of a pastel color conceals what lies under it more or less perfectly (whether this is the ground or an earlier coat of color), so that the uppermost coat determines the appearance at any point completely, or very nearly so. The theory of the

covering power of a pigment is of the greatest importance in the consideration of many points in the other technical methods as well as in pastel, so I hope you will give all your attention here.

Suppose we consider the white pigments first. Every white pigment, precipitated chalk as well as any other, consists of very fine grains of a substance which is in itself colorless and *transparent*. It is very easy to observe that colorless, transparent substances become opaque and white when they are in a state of very fine division. Snow consists of small crystals of transparent ice; the white spray of the sea is nothing but particles of transparent water. But the white color is not produced by fine division alone. There must be present at the same time the alternation of small particles of two transparent substances of very different refractive power, — ice and air, for example, or water and air. Powdered glass is white and *covers* well for the reason already given, but if it is mixed with a substance of about the same refractive power, such as oil of turpentine, a very nearly transparent mass is produced which has no covering power whatever.

The reason for this difference is to be sought in the *reflection* of the light. If you wish to see

just what this means, take a piece of common window glass and try the following experiment.

Turn your back to the window and hold the piece of glass upright and a little obliquely. You will see an image of the window reflected from the front surface of the glass. This image is not as bright as it would be in a real mirror, which indicates that not all of the light is reflected from the surface. Part of it enters the glass, for if you look closely you will see another, weaker image of the window by the side of the first one. This is formed by the light which enters the glass and is reflected from the back surface. But even where the two images overlap the reflected light is not nearly so strong as in a real mirror, so we may be sure that a part of the light has gone on through the glass. This is by far the larger part, for if you turn around and hold the glass between your eye and the window, you will find that the part of the window which is shut off by the glass is only a little darker than the rest.

Now, if instead of the single sheet of glass you use a heap of such panes and try the same experiments, you will find the reflected light stronger and the transmitted light correspondingly weaker. The reflection in such a pile of

plates is of an almost metallic character, especially when the individual plates are very thin and clear, which means that the light is much more *completely reflected*. It is easy to see why this is; the light that passes through the first plate is in part reflected by the second, and the third plate has the same effect on what gets through the second. The more plates you use the greater the proportion of light which is reflected and the less the proportion which gets through; and, finally, you can imagine that when the glass is split into an unlimited number of very thin plates no more light can get through because it is all reflected. This condition can be approached very closely by heating a transparent piece of mica. It splits into numberless thin plates which cling together loosely, and the result is a silvery plate which reflects light very strongly but does not let any through.

Now comes the principal experiment. Divide your heap of plates into two equal parts, and lay the plates of one heap on one another after wetting each with water. In this heap the plates are not separated by air but by water, and you will see at the first glance that the wet heap allows much more light to pass than the dry one and

that it reflects much less. Directly comparable with this is the fact that wet chalk is much darker in color and covers much more poorly than dry. The theory at the bottom of this is: In order that reflection may take place at the boundary surface between two transparent substances, these two substances must have *different properties* (glass and air, or water and air). Where water meets water, and we have two substances with the same properties, there is never any reflection. The property which determines the proportion of reflected light is called *refraction*, and there is a law which states that, other things being equal, the greater the difference in the refraction of the neighboring layers the greater the proportion of light which is reflected at their boundary. The numbers which express the refraction in various substances are as follows: air 1.00, water 1.33, oil 1.48, glass 1.53, chalk 1.57, Permanent White 1.64, Zinc White 1.90, Flake White (lead carbonate) 2.00. The difference between air and glass is 0.53, while that between water and glass is 0.20. This accounts for the much smaller reflection within the wet pile of plates. It will also be noticed that all the other solids in the list show

a greater refraction than glass, so that they transmit less light and reflect more than glass does under the same conditions.

Precisely similar relations exist when a pile of irregular fragments takes the place of the pile of smooth plates. The regular reflection disappears when the plane surfaces are absent, but the light is now reflected in all directions, so that the surface appears uniformly white. This is why snow, sea foam, powdered glass, etc., appear white.

It will now be evident also why such a powder covers well or not. Suppose the various white powders laid on a black ground to such a depth that the black color of the ground is completely hidden. This requires that reflection of the incident light shall be practically complete. This result was attained the more perfectly in our plate experiments as the plates were more numerous and the difference in refraction between the plates and the binding medium larger, so we can conclude that a white pigment covers the better the finer its state of division and the greater its refraction. It is also evident that the covering power is lessened and the color approaches gray when any other substance, such as water or oil,

takes the place of air about the particles. Oil decreases the covering power more strongly than water, because it has greater refractive power. Flake White (lead carbonate) has the highest refractive power, and it therefore covers best and is least influenced by oil. Chalk has the least covering power and is therefore made gray by the use of such media as oil or water.

Here you have the explanation of all the phenomena which appear during the fixing of pastel pictures. When the fixing solution is put on the picture turns much darker because much less light is reflected from wet chalk than from dry. After the evaporation of the water and alcohol the picture does not return to its original condition because casein is left between the grains of color, and this creates an "optical connection" between the particles, allowing light to pass, so that the coating loses in covering power. The effect of a fixative will, then, be less when its refractive power and the quantity of material necessary to hold the grains of pigment firmly are small.

Both these conditions are well fulfilled by casein; hence the satisfactory characteristics of this medium. It is quite probable that still

more advantageous combinations of these two properties may be found; but it is impossible to produce a fixative which will leave the picture wholly unchanged, since it is physically impossible to bind the grains without at the same time producing optical connection between them.

I will close to-day's theoretical letter with this practical result.

VI

MY DEAR SIR:

There is a good reason why I chose only black and white, and the gray which results from mixing them, as the subject of discussion in my last letter. The same considerations apply with slight changes to colors, in the narrower sense of the word.

Take a piece of colored glass in your hand as before, choosing preferably a rather bright color (green or orange, for instance), and look at the image of the window formed when you turn your back to it and hold the glass against a dark background. The image produced at the front side of the glass you already know about; it shows the natural colors of objects, since it is formed by light which is reflected unchanged from this surface. Now look for the other image, — the one formed by reflection from the *back surface* of the plate of glass. It is slightly displaced with respect to the first image and therefore easy to recognize, and it will become still plainer if you turn at a slight angle to the window. This image has the

color of the glass, and you will readily see that this must be the case, for when the colorless daylight passes through the glass it becomes colored. This is the most important property of colored glass. In this case the light has not merely passed through a single thickness of glass, as would be the case if you looked at the window through it, but it has been reflected at the back surface and has passed back through the glass again before coming out in front. It is therefore as strongly colored as would be the case if it had passed through two plates of glass of the same kind. The whole effect of pigments depends on this phenomena, for they are substances similar in their properties to the colored glass. They allow light to pass, but give it color at the same time. While a colorless, transparent substance in a fine state of division reflects light unchanged, that is as white light, a colored pigment reflects colored light, and covers well when it has great refractive power and is in a fine state of division.

Your first question will be, How does the pigment *color* the light? The answer is, By taking away or destroying a part of the white light. We learn in optics that white light can be decomposed into light of a great many different colors

by allowing it to pass through a glass prism. If these different colors are all recombined, we get white light again, but if a part of the colored light is removed, the remainder will also be colored after it is collected. Colored bodies have the power of destroying a part of the light that passes through them. They change it into heat, when of course it ceases to exist as light, so the remainder of the light is colored when it emerges.

A pair of colors always belong together under these circumstances, — the one which is absorbed and the one which remains. If red is removed, the remainder will be green after it is collected again, and vice versa. Such pairs of colors are called *complementary* colors. Red and blue green, golden yellow and blue, green yellow and violet, are examples, and there is of course an infinite number of them, since any part can be removed from the total which makes white light with the production of a complementary color. Each pair is reciprocal; that is, if red is removed blue green remains, if blue green is removed red remains, etc.

This will be, for the time being, explanation enough to enable you to understand the simple phenomena in the technique of pastel. Ultramarine has the property of taking away part

of the white light so that the remainder consists principally of blue, mixed with some violet and red. The white light passes into the heaped-up particles of pigment and is reflected from their back surfaces, reaching the eye as blue light. Not all the light which reaches the eye is blue, for white surface light from the surface of the outside row of pigment grains is mingled with the body color. This is, however, smaller in proportion as the pigment granules are smaller, its amount being very small indeed in the case of finely ground colors.

You will probably have noticed that the Ultramarine which you mixed with water and gum in making pastel was a very much darker blue than the dry powdered pigment in the finished pastels, and you know that in general dry pigments always look much lighter in hue than wet ones, whether mixed with water, oil, varnish, or any other liquid. The reason for this was explained in the fifth letter. If the interstices between the granules are filled with a substance of greater refractive power than air (and all liquids show much greater refraction than air), the reflection from the back surfaces of the pigment granules is weak. The light must therefore pass

through many granules one after the other before it is reflected to any extent, becoming much more deeply colored. Under these conditions a larger proportion of the light is absorbed, and the color is therefore purer as well as deeper.

The lightening produced in pastels by the addition of chalk is now a simple enough matter to understand. The white chalk particles in the mixture lie between the blue-producing granules of Ultramarine and they send back white light practically unchanged, so that the reflected light contains blue and white mingled together. The granules are so small that we cannot distinguish between them, and we get the effect of a light blue, that is a blue color containing a good deal of white. Such mixtures also appear deeper in color when wet, for here too the light penetrates deeply into the wet mixture and is affected by more Ultramarine granules than when the mass is dry.

Now remember that the application of a fixative produces the same optical effect as the presence of moisture but in less degree, and you will easily see why a pastel picture remains a little deeper in color after fixation. You now have the most important points in the optics of pastel

work, with the exception of the part which applies to *mixtures*.

The theory of color mixtures has been treated so thoroughly and satisfactorily by Helmholtz, Brücke, and others, that I need mention only the most important points here.

Suppose that various regions of colored light are removed from average white light in the way already explained, the remainder being then emitted to form the complementary color. This will give an infinite series of colors connected in pairs. Now you may vary each color in either of two ways. First, you may suppose the color to change so that it gets brighter and brighter or weaker and weaker, without ceasing to be the same color. A green, a blue green for instance, may be changed from the weakest to the brightest blue green, and the differences we call differences in the *intensity* of the color. We may, on the other hand, without changing the intensity of the color, cause it to become less and less green until it finally becomes merely a gray, and the differences in this case are called differences in the *saturation* of the color. The intensity depends on the total quantity of light which reaches the eye, the saturation on the proportion of colored

and colorless light which reaches us. A layer of color is bright when the surface light is acting, but it is at the same time less saturated as more surface light is mixed with the body color.

If we examine any colored light by decomposing it into its constituents, the light from a saturated color would be characterized by the fact that it contains only a comparatively small region of color, all the rest being absent. A saturated blue green would show, when analyzed with a prism, only a blue-green light and nothing else. As a color becomes less and less saturated it contains light of more and more colors, and in a neutral gray all colors are present in the same proportion as in white but in less intensity.

Now what happens when two colors are mixed? To arrive at the right answer to this question it must be kept in mind that there are two fundamentally different ways of mixing two or more colors,—by *addition* and by *subtraction*.

If green light and yellow light are thrown together on a white screen by two projection lanterns, the eye receives the sum of the two lights and addition has been the result. But if the yellow glass is put in the path of the beam from the projector which is already provided with a green

glass, it removes from the green light (in which especially the red of the spectrum is lacking) the colors (especially blue violet) which when taken from white light leave yellow, and the resulting beam will be lacking in *both* these regions. Helmholtz showed many striking examples of the very great and fundamental difference in these two ways of mixing colors. Green is formed from blue and yellow by subtraction, but when these two colors are added white is the result, and of course additive light is brighter than subtractive, other things being equal.

The phenomena of subtraction are by far the most frequent and important in the ordinary mixing of colors, and we are accustomed to make green by mixing blue and yellow, but it is also possible to produce additive effects in painting. To attain them the colors to be added are laid on side by side in points or spots which are kept as small as possible, instead of laying on the colors over each other. If, then, the eye of the observer is far enough away so that the individual points can no longer be distinguished, the retina receives an impression corresponding to a superposition or addition of the two colors. The Pointillists or Neo-impressionists make use of this method.

It will be evident, from what has been already said, that a color effect of this kind fits into the arrangement of colors according to intensity and saturation just as well as an effect produced by subtraction. But in the two cases different relations of colored pigments and white must be chosen to produce the same effect. It is also evident that no results of a fundamentally different or more far-reaching nature, either as regards intensity, depth, fire, or whatever the color effect may be called, can be produced by the additive method of mixing colors which cannot be produced by the ordinary subtractive method of mixing. In either case one has the same scale, from the whitest white to the blackest black, which pigments are capable of giving, but the method of attaining a given color effect is different in the two cases. A further difference arises from the necessity—a purely technical one, of course—of giving to the individual spots of color a considerable size as they are laid down side by side in the additive process. This makes fine drawing difficult. But when the spots of color are almost indistinguishable there is produced a psychophysical secondary impression, a *flickering*, which is unattainable with a smooth coat of color,

and in this there is to be found the technical advantage of this particular method. It is immediately evident that for the production of certain effects such a means may be of great value, while there are numberless other effects which must be produced to which this special optical method is not applicable.

When we apply these considerations to the technique of pastel we find that it is usually subtractive colors which are produced by mixing; this is especially true when the individual pigment granules are very transparent. Pigments which combine a somewhat coarser grain with less transparency sometimes show mixture effects like those produced by addition. The artist very soon gathers the necessary experience on this point as he works. Pastel offers good possibilities in the direction of a purely additive method, the first color being put on in short strokes or points, and then, after fixing, the second color is worked into the vacant spaces. The mechanical mixing of colors put on one after the other is prevented by a fixation between each two coats of color.

VII

MY DEAR SIR:

You have been experimenting with the colored glass according to the directions given in my last letter, and now you ask me why its color seems so much stronger and more saturated when it lies on a piece of white paper than when you simply look at the white paper through it. First, let me express my approval of the correctness of your observation, for the very fact that you noticed this indicates a well-developed sense for seizing and examining unexpected effects. This is a rarer gift than you may think, for most people only see what they expect to see.

The reason is that when you look at the white paper through the colored glass the light from the white paper only passes through the glass once; but when you lay the glass on the paper the daylight must pass through the glass once to get to the paper, and then back through the glass to your eye. The effect produced is the same as though the light had passed through a piece of glass twice as thick and the color is correspondingly deeper.

This forms a very good starting point for the theory of the process to which one naturally turns at this point, — that is, *aquarelle* in the narrower sense of the word. It is evident that this name originally indicated simply a process in which water is used as a medium for diluting and carrying the pigment. But you know that water colors are used in two different ways, — in aquarelle and in “body water color” processes. Formerly every one avoided the use of these two processes side by side in the same picture with a sort of religious scruple. This feeling still holds among English painters, I believe, but nowadays international usage has overcome this prejudice and the motto is, Use any method that gives good results.

As is the case with all such rules, there are real facts behind which led to the dogma, and it is only because the reason for the phenomena in question was not understood that such a summary injunction was ordered. “The baby was to be thrown out with the bath water”; that is to say, the good and useful combination was forbidden along with the unpleasant one.

There is in fact a very important difference to be kept in mind, one which has been known since the days of the earliest authorities on painting,

and that is the difference between transparent and opaque colors, or, as they are now termed, glazing and body colors. In aquarelle in the narrower sense transparent colors are used as far as possible, while in body water-color painting opaque colors are the rule. What determines the covering power of a pigment has been explained in the third letter. A body color gives out only such light as has received its colored character by absorption and reflection in the granules of the pigment itself. A glazing color, however, acts like a piece of colored glass lying on white paper: the color of the background shows through and the glass only takes out of this such colors as it absorbs. The usual ground for aquarelle is white or slightly tinted paper, and the effect on the eye is a combination of the light from the white paper and the transparent color which has been laid over it.

The water-color painter therefore makes up his palette largely of such pigments as are transparent in character. If you remember the theory of the covering power of a pigment in earlier letters, you will immediately see the properties which a pigment must possess to be applicable to work in water color, since the covering power is stronger as the refracting power of the colored substance

is greater. Those colors will be the most transparent whose refraction is least, and this you will see confirmed in every case. The lead pigments, which have in general a very high refractive power, have no transparency, while "lakes" of all kinds are combinations with alumina, which is a substance of very low refractive power.

Furthermore, the individual grains of color are the more transparent the smaller they are, and from this it follows that pigments which are as finely ground as possible should be used for aquarelle. The differences in quality of the various kinds of commercial water-color paints depend, in fact, almost entirely on the difference in fineness of the ground pigment; for the finer grain increases not only the transparency of the color but also its power of holding to the ground after it has been laid on. It is immediately evident that a granule of color will be less easily displaced from its position by a later stroke of the brush if it is very small. It finds the hollow more easily, in which it is protected and hidden from the hairs of the brush, and upon this depends the property of very finely ground water colors to hold firmly after once becoming dry and not to be easily disturbed by a later wash.

You have probably had a question on the tip of your tongue for some time about the medium for water-color work. The answer is a very simple one: gum arabic is generally used. As you know, it is soluble in water, and upon this depends the property of an easy rubbing up with water which belongs to cakes or pans of water color, and the further property by which a heavy coat of water color does not resist a wet brush. When the coat is thin the pigment granules find a hold in the roughness of the paper; but when the coat is thick most of the granules are held only by the gum, and they therefore lose their hold when the medium is disturbed. One can, indeed, lay on a new coat over a strong color by rapid and skillful work, provided the coat is finished before the gum underneath has time to dissolve; but as soon as a wet spot is touched with the brush, the coat beneath, which has been dissolved and softened, is disturbed. This difficulty suggests the question of using a medium which would remain undisturbed after drying, when a further coat is applied. There are such media, and we shall discuss them later when we come to *tempera* painting. With this advantage they always bring an evident disadvantage, namely that colors mixed

with them do not keep at all, since when they are once dry they become insoluble. We will, however, leave this discussion for later treatment under the head of tempera painting, and in using aquarelle we will remember the solubility of the medium and treat it accordingly.

Those parts of an aquarelle picture which have been produced by means of a thin coat have the same appearance after drying as in the wet state; but a place which has been covered heavily becomes somewhat duller after drying. This expression indicates simply that more diffuse surface light is reflected from these places after drying, and the optical relations which hold here are easy to understand in the light of our earlier discussions.

You will remember that less reflection appears as the difference in refractive power between the granules and the surrounding medium becomes less. In the wet picture the surrounding medium is water; in the dry state it is partly gum and partly air. The gum has about the same refractive power as the pigment, and a mixture of the two has nearly the effect of a piece of colored glass. Air has a very much smaller refractive power, and those granules which are surrounded by air give

nearly the effect of an opaque color. When the coat is thin sufficient gum is present to give each granule enough medium to insure transparency, while if the coat is thick this is not the case unless one adds gum or a similar substance. Now in the wet picture the effect of the gum is produced by the water which is present, but on drying water is replaced by air, especially when the coat of color is a heavy one. The action of varnishes and the like in "bringing out" a picture which has "flattened" has the same explanation as the flattening of a picture on drying. The varnish surrounds each pigment granule with a medium of optical properties similar to its own, just as is the case in the wet picture, and the effect produced is that of a transparent piece of colored glass. Any solution which leaves a glassy residue can be used as a varnish,—gum arabic, for example. But in order to avoid all danger of disturbing the colors by dissolving the binding material alcoholic varnishes are usually applied, since alcohol does not dissolve the gum. A solution of bleached shellac in alcohol is useful, and the varnish which is sold in the shops under the name of Zapon varnish seems to me to be better still, since it is completely colorless and therefore free from all

danger of turning yellow. This consists of a solution of celluloid in amyl acetate, and it has the special advantage of not entering the pores of the paper as the alcoholic varnishes do. Paper, which is the usual ground for water color, plays an important part in the color effects produced, since it has to reflect the light. The thin coat of color acts like a transparent medium and in a twofold way: the incident light is colored as it passes through this coat to the paper as it would be by a colored glass, and it is subjected to the same influence a second time when it is reflected from the paper. In order that this action may be produced, extremely thin layers of pigment must be laid on, especially for the more intense colors. If the pigment is not a perfectly stable one and a slow chemical transformation takes place, what would be quantitatively an exceedingly small change is enough to cause an action which is visible to the eye. Aquarelle pictures fade under the action of light in an especially high degree unless they have been made with the most unchangeable colors; it is for this reason that Turner's water colors in the London National Gallery are preserved under curtains to protect them from the action of light.

The well-known difficulty of producing in water color broad surfaces of equal coloring or regular gradation is directly connected with the fundamental principle just described; for the whole effect depends upon the thickness or the density of a transparent coat of color, and this thickness must be perfectly even or have a perfectly regular gradation if the effects mentioned are to result. This difficulty is present neither in pastel nor in body water color, for in these processes the layer of color is made so thick that the effect of the ground disappears, and it therefore makes no difference when the coat of color is thicker at one place than another, since no further change in the effect is produced. On the other hand, the effect produced by water color is that of great purity and clearness, and this depends upon the fact that all the light passes twice through the colored transparent layer. In the case of heavy covering pigments a mixture of colored light from the pigment and white light by reflection at the surface reaches the eye and the transparent character is lacking.

If you ask for my general opinion of the value of aquarelle, I must say that I see no very great advantages in it. Its most important virtue is the

optical effect produced by the transparent colors. The small amount of binding medium necessary is an advantage, and the life of the picture is not shortened as a consequence of changes in the medium. And since the paper which is used as ground is durable in a very high degree, no causes are introduced which might produce rapid depreciation from this side. But the fact that the entire effect of the picture depends upon the strength and character of an exceedingly thin layer of pigment is a very considerable disadvantage; and upon this depends, on the one hand, the difficulty in producing a picture and, on the other hand, a very great sensitiveness to chemical changes in the pigments themselves. These circumstances decrease the freedom of the artist considerably, and you will find that nowadays artists who use water colors for large work replace the pure aquarelle methods by mixed ones which are less subject to these disadvantages. The widespread use of aquarelle among amateurs seems to have its reason exclusively in the simplicity of the necessary apparatus, but because of its technical difficulties it is of all processes the least fitted for a beginner.

VIII

MY DEAR SIR :

I perceive with much satisfaction, from the questions which you ask, that my explanations have really given you food for thought, which was my principal aim. I will answer your questions in their order.

To begin with, you wish to know why ox gall is used in aquarelle, — that is, how it acts. You know that this substance aids in producing a smooth coat of color and prevents the tendency of water color to gather into drops. The cause lies in the *surface tension* of water, which is very large. As a result of this property water has a tendency, greater than that of any other liquid, to take on as small a surface as possible. Since it is evident that a round drop has a smaller surface than a broad layer, water tends always to go from the state of a layer into drops, and wherever the ground is not wet and the maintenance of a layer insured drops are formed. This may be very easily seen in the case of drops of dew on leaves, where wetting is prevented by a coat of hairs or

waxy material. Ox gall acts in two ways: first, it lowers very greatly the surface tension of the water in which it is dissolved; second, it aids in wetting the paper by transforming whatever fat remains on the surface (this is in most cases the cause of poor wetting) into many small drops and so renders it harmless. This latter property of *emulsification* is of the greatest importance in tempera work, and we shall consider it more exhaustively when we take up that subject.

Then you ask what causes the curding or separation of many water colors, and in reply I can only give you a few conjectures. As a result of the fine state of division of many aquarelle colors a condition is produced very much like that which is called in chemistry the *colloidal* condition. This is something about halfway between a mechanical suspension and a true solution. Substances in colloidal solution are easily separated and precipitated in flocculent form when salt-like substances are added to the solution. It seems to me quite possible that the ordinary water taken from the city pipes causes a precipitation of this kind as a result of the salts which are always present in it. Different colloidal solutions show great differences in sensitiveness

toward salts, and it is therefore easy to understand why certain colors should show this effect more than others. If this theory is correct, it shows us immediately the means of avoiding the difficulty; it is a question of preventing precipitation, and I see two ways of doing this. The first is to use water which is free from salts. Distilled water and rain water contain no salts and would probably not produce this effect, but this means would be of no use if the paper itself contained salts, which is very often the case. Alum and sodium thiosulphate are often present in paper, so that another means of avoiding the difficulty must be chosen. It is a very general fact that a colloidal solution is much more difficult to precipitate when other colloidal substances are present, so if one adds a little white of egg, gelatin, or mucilage (colloidal substances) to the water used for mixing the paints, precipitation would not occur so easily when the water or the paper contain salts. Try this the next time you have difficulty from this cause, and be sure to let me know the results of your observations.

You then ask why a pigment mixed with a heavy covering white shows an entirely different result from that produced by spreading it to the

same thickness as aquarelle color on white paper. Colors which are mixed with white always appear much "colder." We call a color colder when it contains more blue and your question is therefore, Why do colors appear bluer when they are mixed with white?

The cause lies in a phenomenon which Goethe called the "fundamental phenomenon of color," — that is, that a translucent white or milky substance looks blue when seen against a dark ground. You can convince yourself of the fact if you pour thin milk into a vessel with dark walls; you will see around the edges a pronounced blue rim where the dark vessel is visible through the white milk. The physical cause of this phenomenon is somewhat difficult to explain, and you will find more about it in Brücke's *Philosophy of Color*. The most important point is this: very small particles reflect light of short wave length, that is blue and bluish-green light, most completely. These therefore predominate in the light which is reflected by the milk, while the light which has passed through has lost these same rays and therefore looks yellow or reddish yellow. This is the reason why the shadows in the distance look blue, for there we have the slight cloudiness of the air

against the dark background. On the other hand, when the sun is low its light passes through this cloudy air and appears yellow and red. In all this very much depends upon the fineness of the particles which cause the cloudiness, and the blue and the red are purer as the particles are finer. Larger particles, those of fog for example, do not show this selective reflection and appear uncolored, that is gray, when viewed against a bright or a dark background.

Now when you mix white with a colored pigment, Burnt Sienna for instance, the white particles act like a cloudy medium against the dark background of the colored pigment, and this adds blue to the reflected light. This would be avoided if you covered the place with white first and then laid on the Sienna without mixing it with the white.

These relations give us an excellent means of reproducing certain natural phenomena easily and completely. The blue distance can be reproduced in a much more natural way by laying on a transparent white over the shadows than by diluting a color to the same shade; and it is well to consider in the case of each natural phenomenon how it is really produced optically, and to choose as far as

possible a corresponding process for its reproduction. The transparent character of the skin shows a number of these "colors of cloudy media" which can be produced in the same way. Since this process can be carried out most easily and in the most manifold way in oils, we shall take it up more fully at that point. In aquarelle the changes on drying are most evident in the thin layers of transparent color which are put on over heavier colors, so that it is exceedingly difficult to calculate in advance the final effect of such a coat.

This brings us naturally to the technique of water color with heavy covering pigments, — the so-called *body water-color* process. Very much the same may be said about the optical peculiarities of this process as has already been said about pastel, since the light and shade of pigments is, in this case as well as in the other, produced by mixture with white. In this case, however, chalk is not used, but a substance with a much higher index of refraction, — Permanent White (barium sulphate) or Zinc White (zinc oxide). Zinc White has the very unpleasant property of cracking when used in heavy coats; that is, the coat splits into small blocks after drying. Permanent White is much better in this respect. The higher index of

refraction is necessary because the color is laid on wet,—that is, it is mixed with an excess of water. It therefore appears darker in this condition and with less covering power than after drying, when the water has all evaporated. Since it is rather difficult for the artist to use colors which dry into effects very different from the ones produced when they are laid on, it is best to use this white of greater refractive power, and by its aid and the use of sufficient quantities of binding material provide conditions which shall make the final differences as small as possible. It is impossible to avoid them completely.

A problem arises here which will follow us through all the succeeding processes. The binding substance forms a solid body with the heavy coat of dried pigment. This body lies on the ground in the form of a plate of varying thickness and irregularity. This plate has properties with respect to changes of temperature and moisture which are very different from those of the ground, and there is danger that the material of the painting will break loose from the ground and fall off in smaller or larger pieces. This happens because the expansion brought about by the influence of temperature and moisture is different in the two

layers, so that the painting and the ground, which were of equal size under certain conditions, become of different size under other conditions. If either the substance of the picture or that of the ground is flexible, differences of this kind will not be very harmful, for one of the two will force the other to follow its changes; but when both are stiff and resistant strains will occur which lead at first to cracks and finally to the peeling off of the picture.

In pastel, even when it is fixed, the substance of the picture is so soft and flexible that there is no chance whatever of cracking or breaking; but body water colors, laid on heavily, may form a horny mass of considerable hardness. In this case a possible danger may be avoided by the use of paper with a rough surface. The mass of color is pressed between its fibers and held fast by them. Body water-color pictures made on a smooth, hard substance, such as parchment, have not much chance of being very durable and would probably be less durable as the coat of color is made thicker. We shall meet this condition again and again in our later discussions. There is nothing which produces shorter-lived results than "pasty" painting.

IX

MY DEAR SIR:

Indeed, I have not forgotten fresco, the "noblest of all processes," as you call it, and it comes in just at this point, for it is in fact a water-color process, a special medium being used. Just why you give this title of excellence to the process is not quite clear to me, especially since you add that you yourself, like most painters of to-day, have had no opportunity of learning to use it. If you look at the frescoes on the Berlin Museum or those on the New Pinakothek in Munich, you will find it hard to say much in favor of fresco as exemplified by these almost indistinguishable ruins, which are, after all, only a few decades old. However it may be under climatic conditions more favorable than those we have in central Europe, it is certain that with us this process has proved itself absolutely untrustworthy as far as durability is concerned.

We shall have to examine the special limitations of this process as we take up the individual points concerning it. In fresco we use a special

kind of water color. The painting is made on a damp, plastered wall and the color itself is mixed with lime. The water which is used has dissolved a little lime (about a third of one per cent), which remains behind when the color dries, changing at the same time, under the influence of the carbonic acid of the air, into calcium carbonate. Since the setting of the mortar depends upon the same process, close connection between the picture and the ground is insured; for since the binding material consists of the same substance as the ground, the effect of external conditions is the same on both and the principal cause of cracking and chipping is avoided.

But the picture is exposed to all the disturbances which can affect its ground, the wall. The most dangerous of these is the crystallization of dissolved substances on the surface. Whatever soluble substances were in the wall when it was built or have since gotten into it, are all in the course of time unavoidably deposited on the surface. When the wall becomes alternately wet and dry by changes in the weather as well as by direct wetting by rain, the moisture in the damp wall dissolves whatever substances are present until it is saturated. Then the wall dries, and

the water which is on the surface, that is on the picture, evaporates and leaves behind it a corresponding amount of dissolved substance. The moisture which is present in the interior of the wall then creeps to the surface as a result of surface tension (capillarity) and the same action as before takes place, so that all the substances which are in solution in the wall are transferred to the surface. This process is repeated until finally all the dissolved substances have been removed from the wall and deposited on the picture.

Soluble substances can get into the wall in two ways. First, they can enter with the material of the wall, principally with the stone, in less degree with the mortar. A means of avoiding this is to use only such materials as have completely lost their soluble constituents, either by a natural or an artificial use of pure water often changed. In the same way, one must avoid the addition of soluble substances with the water, the mortar, and the colors used in making the painting. The second way by which soluble substances can get into the wall is by diffusion of moisture upward from the earth. This water always contains dissolved substances from the material of the soil, and when it diffuses up through the wall and

experiences the action pictured above, we have again the conditions for the separation of dangerous precipitates. The means of avoiding this is a well-known one. A waterproof layer is introduced between the lower and upper portions of the wall, which prevents the capillary rise of moisture from the soil.

Beside these dangers to the life of a fresco painting there must also be mentioned the chemical action which is inherent in the lime used as a binding medium. Lime is a strongly basic compound with a most destructive action on many substances, especially organic ones. The oxidation of organic pigments by the air is very often greatly accelerated by lime, and it also exerts a decomposing action on saltlike substances. For example, Prussian Blue is instantly colored brown by lime, with the separation of ferric oxide and the formation of calcium ferrocyanide. In fact, the ochers, the earth colors, Ultramarine, and a few other substances are about the only colors which are safe for fresco work.

Fresco colors are laid on wet and are intended to finally show their effect in the dry state. Since lime is so insoluble, only a very little binding material remains between the granules of pigment.

In the dry picture it is usually air which separates these granules, and therefore a maximum covering effect and a maximum reflection of light are produced, in accordance with our previous explanations; but the color is by no means in this condition when it is being laid on. There is water between the granules, and the reflection is slight because the refractive power of lime is not very great, so that the pigments of the picture with their whitening substances (calcium carbonate and lime) are much deeper and purer in color than they are after drying. This gives rise to a very great difficulty, since one cannot paint with respect to the appearance of the picture during painting but must take into account the later effect of drying. This difficulty is the more insuperable because a change or a correction in the picture after it has once dried is practically impossible. Lime colors added to the dry picture do not combine firmly with the ground, because the surface is already entirely transformed into calcium carbonate. One must therefore turn to the other technical methods for subsequent changes and additions to the rapidly painted picture, and it is unnecessary to call attention to the fact that changes in appearance in these added parts will

be different from those which take place in the fresco colors. However carefully the retouching may be done, it will be in vain, for sooner or later it will show itself; new retouching will be necessary, and so on *ad infinitum*.

In my opinion, the present neglect of fresco is in no way a sign of the sad degradation of modern art. Fresco has been given up for the same reason that we have given up the stagecoach, — because more convenient methods have driven it out; and this applies just as well to the artistic side of the question as to the matter of durability. The artistic disadvantages are to be found in the necessity of working piece by piece, in the limitation of the palette, and finally in the great change which takes place in the colors on drying. It may have been all right to work piecemeal at a time when the problems of the lighting of a picture and of general color effects had not yet arisen, and the artist could confine himself to bringing together in a picture beautifully colored details according to rules which led to a pleasing general effect; but it is a different matter to work toward broad and definite light effects with such a technique, and so we find that, from the time when these problems began to interest artists,

every one has turned away from fresco and taken up oils,—a method of incomparably greater promise in this respect. The same is true of the other side of the question,—the limitation of the palette and the lightening on drying. You need only to read over the descriptions of Schick concerning his experiences with Böcklin while the latter was working on fresco at Basel, and these things will come home to you very clearly: “The first picture dried in the most unexpected way. The atmosphere and the cypresses and other trees came out as Böcklin had expected. The shadow side of the house is very much too light because he used in the shadows a good many colors mixed with chalk. The meadow is much too light because Böcklin calculated too much on the effect of the dark gray ground, which has dried to a much whiter color than he anticipated. Those spots which were bright yellowish green where the low grass was visible between the higher shrubs now appear as dark green spots on a light gray ground, and so on. Many changes have also taken place in the grass of the foreground: the bright green strokes which were laid on over the middle tone of the grass are now no longer to be seen, and the result is an unmodeled surface of

color like the medium tone. The dark gray middle tones (for which the ground color was used) have become very pale on drying, and the light green blades of grass which were painted on it are darker than the background. The blue flowers (Smalt and Morelle's Salt) are darker than Chrome Green, and the light yellow flowers (Gold Ocher) are almost as dark as the green grass."

You will probably offer the objection that all these troubles arose from Böcklin's lack of experience in the technique of fresco and that an artist who had painted much in it would no longer make mistakes of this kind. That is perfectly true, but it is a fact that even the experienced artist can calculate only approximately the effects desired and that his final results are in large measure dependent on chance. He will therefore be obliged to confine himself to a certain range of modes of expression and he will find it difficult to extend this range. New experiments are dangerous on account of the impossibility of making subsequent changes. To summarize my own opinion of fresco painting very briefly, I do not think that it deserves encouragement in any way, but rather that it should be given up on account of its deep-seated imperfections.

X

MY DEAR SIR :

There are a number of things that I should like to say in reply to your assertion that traditional respect should be paid to fresco painting, but it will be better to leave this until our next meeting, when we can discuss them to better advantage. In order that a discussion may be fruitful it is necessary to be clear on a common starting point of some kind, and from this point to reach a further understanding. I do, however, wish to answer one of your remarks at this point. You say that no other technical method has so "grand a style" as fresco, and that it is therefore the most fitting process for monumental painting.

We have already touched on a similar question in a previous discussion. You may remember that I told you then that I got no very distinct meaning from this word "style"; and to this you replied that every painter knew what it meant. So I must try to clear up for myself the meaning of the word. I think I reach your idea when I lay emphasis on the fact that this method, fresco,

does not permit of any desired mode of expression, but has only a limited range; for example, one would hardly desire to represent by its aid a sunset or other natural effect full of color and light. If problems of this kind are to be met, it would be necessary to confine one's self to indications of the effect desired, and a so-called naturalistic mode of expression must be avoided because it would necessarily be insufficient. The finished product must then have something abstract about it, for there can be no question of an approximation to nature, and the artist must seek his effect in the drawing and in the mental content of his representation. I hope that I have expressed the most important point in this, although you will probably miss the elevated tone which usually attends the discussion of questions of this kind. You will, however, admit that similar limitations may be built up for any of the technical methods of painting by fixing a limit to the palette, — that is, to the number and range of colors which are to be used. It is possible, however, in any other process of painting, to set up a style similar to that which is demanded by the nature of fresco, with the difference that problems can be solved by the other process which are impossible in

fresco. This means that we have in fresco limitations which are forcibly set up for the artist and which he could set up for himself in the other forms of painting if it were necessary. For myself, I see no advantage in such a condition but rather a distinct disadvantage.

Let us leave fresco for a time at this point and turn to the remaining methods in the technique of painting. There are two principal ones,—*oil* and *tempera*.

If we kept closely to our system of discussion, it would be necessary to take up tempera next, since the process which bears this name depends upon the use of water as a medium and is therefore an aquarelle method in the broad sense of the word. This is not advisable, however, because there is not at the present time a very exact definition of tempera. It rests, in fact, on the basis of a sort of alchemy, an art full of secret formulæ, on which the progress of modern science has apparently had not the slightest influence. Half-understood directions are taken from old books on painting, improved in various ways, and then most carefully concealed by the inventor as great secrets. A new process of painting, built up in this way, comes into public notice from

time to time with a great noise. Inventors and manufacturers laud it as giving unattainable and unequalled brilliance of color, but they guard most carefully the secret of the medium used in the making of these new colors. It cannot be often enough said that the use of colors of this type is of about the same value to a painter as an investment in South American bonds would be to the father of a family. It is possible that the thing may be worth something, but the probabilities are against it, and no painter who feels himself responsible in any way to his clients should use anything of this kind without knowing exactly what he is doing. Cases where valuable works of art have suffered far-reaching chemical and mechanical changes because of the use of such secret nostrums are very numerous. Cases where the value of a picture has decreased to a very small fraction of its original worth appear so often that there is no necessity of enumerating them. When such changes appear a new secret process is often suggested as a cure and the evil made worse by quackery of this kind. It is usually explained that the old methods of the great Flemish and Dutch artists, whose pictures still remain brilliant and fresh in color after five

hundred years, have become lost arts, and that there is no hope nowadays of attaining similar results. In reply to this it must be most emphatically stated that an equally perfect mastery of our materials is possible, based on our present scientific knowledge, and that pictures can be made which will, in all scientific probability, have a life as long as these. Results of this kind are not attained by the method of the alchemists but by a clear statement of the question. Science will always give a clear answer; if not to-day, in the near future.

There! I think I have spoken my mind clearly on this point. It is to me a matter for sorrow when I find in the descriptions of Böcklin's work what an enormous amount of time this great man wasted in useless, wandering experiments,—time which he could have saved if he had had but a small amount of chemical and physical knowledge. Of course, even the most erudite scientific investigator does not know everything, but he does know *how to experiment*, which is as difficult an art as painting. It is not a question of mixing up ancient recipes and trying them to see whether or not they are worth anything, but a question of setting a clear idea of the effect of each substance

which has been found to give satisfactory results, and then so varying and working out the relations that the desired aim is most perfectly attained. The result usually turns out to be a compromise between various conditions which are partially contradictory. In our own case these are principally two,—optical value and durability. To satisfy one of these fully without disturbing the other is a problem which can only be solved by systematic work carried out in strict accordance with the rules of science. The technique of painting must be developed in the same way that medicine has been, for it is, at the present time, still in an age of quackery and most absurd superstition. To hasten this development is an aim for which a man should do much.

Nowadays nearly all pictures are painted in oils. This process has come into use in its present form since the so-called Golden Age of Italian painting, to which belong the names of Leonardo, Raphael, and Titian. We do not know exactly what process was used by the men who are usually called the discoverers of oil painting,—the two Flemish brothers Van Eyk. A marked difference in the life of their pictures as compared with undoubted oil paintings of a somewhat later

period makes it evident that their process was not oils as used at the present time.

Ernst Berger's assumption that the Flemish process was oil-tempera has a good deal in its favor, but we cannot discuss it here. However that may be, it is a fact that the pure oil-painting process came to the front very rapidly and that it has almost completely supplanted all the other processes.

The reason of this is to be sought in two circumstances. In the first place, this process permits of the application of the two principal methods of laying on color, — *solid underpainting* and superimposed *glaze*. These may be used side by side and superimposed at the same time, and the artist acquires for this reason a larger range of modes of expression than is possible in any of the methods we have considered. The second great advantage is that oil colors look exactly the same during the process of painting as they do after they have become hard, and the artist can therefore calculate his effects at will without any possibility of an unforeseen change in the final picture. This latter advantage is, to be sure, somewhat deceptive, for although oil colors do not change in the course of weeks or months

they are certain to change in the course of decades and centuries. The well-known warm brown tone of old oil paintings is a sign of this. It does not depend upon the original coloring of the picture in any way, but on the change which the oil used as a medium has suffered in the course of time. We will take up this point a little more in detail later. Let us now turn to the chemical and optical properties of oil colors. The medium used in making these colors is either linseed, nut, or poppy oil,—a “drying oil.” By this is to be understood an oil which changes into a resinous, solid mass on standing in the air. You can easily prove that all oils do not do this; olive oil and table oils turn rancid and taste bad after remaining a long time in the air, but they do not become solid. The solidification of such an oil is fundamentally an oxidation process,—that is, the oil takes up oxygen from the air and combines with it to form a solid mass. This is the reason why oil colors dry on the picture or on the palette but not in the tube, where they are protected against the action of the air.

When these colors dry the oil changes into a nearly equal bulk of a resinous product, not to an exactly equal amount, for the volume of the

product is a little smaller than that of the oil, especially after long oxidation. This is the determining factor in the optical character of oil paintings. In the various classes of water colors the principal constituent of the medium, water, evaporates without leaving anything behind it, and the color is, therefore, a rather porous mass which consists almost entirely of the pigments. In the case of oil colors the oil retains its place and the color is not porous after it has hardened, but consists of the transparent resin formed by the hardening of the oil and the granules of pigment embedded in it.

The optical result is as follows: If the pigment granules have high refractive power, the whole mass will have strong covering properties, for although the refractive power of oil is greater than that of water it is less than that of pigment. Water has the refractive index 1.33, oil 1.48, Flake White 2.00. It will be necessary, however, under otherwise similar conditions, to use a considerably thicker coat of color in oil than in body water color to produce the same covering effect with a pigment of rather low refractive power. This determines the necessity in many cases for laying on oil colors very heavily, — that is, putting on a

"pasty" coat. It must be kept in mind that this necessity is a direct evil, and that in the course of time an oil painting goes to pieces the more certainly the thicker the paint has been laid on. I will not deny that this prospect has very often been somewhat of a comfort to me in visiting exhibitions of paintings. If the pigment which is rubbed up with oil has a less refractive power than the oil, the phenomena described in my fourth letter will appear: the light finds little resistance to its passage through the mixture and the latter has in general the optical properties of a piece of colored glass. In order that such a color may produce this effect, it must be laid on a ground which can reflect light, just as in the case of aquarelle in the narrower sense of the word. Colors possessing this property are called glazing or transparent colors. They can be transformed into body colors by mixing them with a body white, but since a part of the white acts like a cloudy medium in front of the darker pigment, such colors are made colder and change toward blue when they are mixed with white. This is especially the case with Madder Red. When this is used as a transparent color it produces an incomparably warmer effect

than when it is mixed with white, in which case it tends toward violet.

By thus embedding the pigment in a medium of comparatively high refractive power a considerable decrease in the white or gray surface light is produced, and it is therefore possible to attain an effect which is determined in any desired degree by the richer body light. On this fact depends in large measure the remarkable color effects of those old Flemish pictures which, because of their optical properties, are to be regarded as oil pictures painted with transparent colors, whatever may have been the technique used in producing them. At the present time these effects appear to be disdained to some extent; perhaps because artists are not sufficiently acquainted with them and also in part because their application demands a more complicated technique than the easy laying on of previously mixed colors.

The second consequence of embedding the colors is an increase in the mechanical durability of the picture. Oil paintings may be hung without any protecting glass, and dust and dirt can be removed from the surface by washing. This advantage is not without its doubts; for while it

may have been important at a time when the manufacture of large and perfect plates of glass was impossible, it is not of much importance now, when plate glass for very large pictures may be had at a price far below the value of the work of art itself. Without the protecting glass an oil painting is exposed not only to the effects of carelessness or vandalism but also to the slow action of the impurities of the air, especially smut and the sulphur dioxide of the modern city. The directors of museums are therefore more and more in favor of placing oil paintings behind glass, and since nothing can be said against this from the standpoint of artistic effect, these mechanical advantages of oils become of less importance.

Of course a glass covering has sometimes the disadvantage of causing the appearance of undesirable reflections from opposite windows or other bright surfaces, which makes it difficult to find a satisfactory viewpoint. These reflexes can be avoided if pictures are not hung vertically but tipped forward at the top, so that only the floor is mirrored in the glass; and if the floor is dark in color, all false light is avoided. The following considerations must also be kept in mind. The ordinary varnishes consist of resins dissolved in

oil of turpentine or alcohol. When such a varnish is to be removed for the purpose of cleaning the picture a corresponding solvent must be chosen. This has also the property of attacking the hardened oil colors, and great care and experience are therefore necessary in restoring an old oil painting. A part of the picture is usually removed with the dirt.

In order to avoid this it is perhaps best to cover the picture with a layer of a substance possessing entirely different properties, and I can recommend for this purpose the so-called Zapon varnish, which consists of a solution of celluloid. If the picture is covered with a coat of this and then with an ordinary varnish, the latter can be removed easily and perfectly at any future time, while the layer of celluloid is not disturbed by oil of turpentine or alcohol.

Oil paintings have considerable disadvantages opposed to their mechanical and optical advantages, since the medium has its part to play in the optical effect of the picture. The resinous oxidation product of the hardened oil is by no means an unchangeable substance: the process of oxidation does not stop, but goes slowly on, the resin becoming brown and decreasing its volume

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more and more. As a consequence every oil painting is in a process of continual change, and this change takes place with a varying velocity depending on the nature of the pigment which is mixed with the oil. This is the cause of the numberless diseases to which oil paintings are subject, and as a result there has arisen a special class of cures for these patients in the shape of so-called "restorers." This is, however, such an extended matter that I must not take it up here.

XI

MY DEAR SIR:

You will claim that I am gradually spoiling all the processes of painting for you by my scientific warnings, so that finally you will not trust yourself to turn over a picture to a purchaser. This is a sensation which always comes to the beginner in the study of physics when his attention is called to the many sources of error in observations. He usually exclaims distractedly that there is no such thing as an exact measurement, which is perfectly true. There is no absolutely exact measurement and there is no absolutely permanent picture. But there are various degrees of exactness as well as various degrees of durability, and a rational understanding of conditions leads to the production of the most durable picture possible under existing conditions. It should be remembered that pictures of considerable durability can be produced in oils if the conditions which are most favorable to good results are maintained. These conditions are of two kinds: in the first place, one must endeavor to insure

to the picture the greatest unchangeableness, or rather the least possibility for change; in the second place, the picture must be so painted that the unavoidable changes can be compensated without any danger to the picture.

It is only the changes in the medium which need to be considered here, for I am making the assumption that the painter uses none but durable pigments. There is a quite sufficient variety to be had in good colors, and I will not take them up again here, since the embedding of the pigment granules in the resinous mass produces an especially complete protection against the action of air and its impurities, so that a pigment which is of itself not very stable becomes stable when used in oil.

You already know that the setting or hardening of an oil color depends on its taking up oxygen from the air. The subsequent undesirable changes in a picture depend on the same cause. The conclusion is that air should be kept away from the finished picture as completely as possible. How important this matter may be is shown by the fact that in pictures painted on linen the parts which are protected by the wooden frame from the direct attack of air always show a much

better state of preservation than the free parts of the picture. The old Flemish pictures which are so well preserved are painted on wood, the attack of air from the back of the picture being almost completely excluded under these circumstances.

Considered from this point of view, it is evident that the usual choice of linen for oil paintings introduces a factor which decreases the life of the painting by perhaps one half. This may be bettered by the use of means suggested by the above considerations. If an older picture painted on linen is in question, the first thing to do is to prevent the entrance of air from the back of the painting, which is most easily and most effectually accomplished by covering the back with tin foil fastened by means of an alcoholic solution of shellac. This coating can be very easily removed if this becomes necessary for any reason, and it can produce no evil effects on the picture, especially when the coat of tin foil is protected by a layer of varnish. Such a coat is also a shield against the absorption of moisture by the linen, and one of the causes of cracking is removed. The same process may be applied to new pictures, but for reasons which I will give you immediately it is

advisable not to put on the layer of tin foil until the picture is at least a year old.

By this means oxygen is kept from the back of the painting. It is customary for the painter to cover the front with a varnish which has this function and others as well. In accordance with what has been said in the previous letter, a glass covering produces still better results. There is no difficulty in carrying out the glazing so carefully that only a very small amount of air can enter, and in this way conditions are produced which insure a far greater life for the picture. Scientific caution demands that certain facts should be mentioned at this point. We have no long experience with respect to other actions which might take place when a picture is shut off from the air in this way, and the statement just made must therefore be taken with reserve. A fear which has been sometimes expressed, that moisture which was inclosed during framing might be dangerous can always be answered by simply inclosing no moisture during the process. We therefore know enough about oil paintings to make it certain that the process just described is, at the present time, the best one and that it will probably give the best results.

What we have just said applies to those properties of oil colors which are inseparably connected with them. Beside the disadvantages arising from these properties there are others which depend on the improper use of oils. These appear especially when several coats are laid one over the other or when the coat of color is very thick, and under these circumstances the layer of pigment loses its coherence and flakes or cracks.

The cause of these evils is a manifold one. It may be said in general that such a splitting of the layer of color will take place when the ground and the layer of color change their surface area in a varying degree, and such effects appear the easier when ground and layer of color are not flexible.

Suppose that the linen is protected from taking up the oil only by a sizing with clay, and that the paint is laid on this ground in a layer so thin that all parts of the layer are bound to the threads of the linen and do not form a coherent plate with each other. Then the possibility of splitting or cracking is avoided; for even when the linen changes its dimensions by becoming moist (when it contracts, expanding again on drying) each particle of color follows the thread to which it is attached. It is quite possible to paint in this way,

especially if one can free himself from the traditional prejudice against bleached linen and therefore chooses a white ground. Such a picture is affected in minimum degree by the darkening of the oil, since this forms only a very small part of the coat of color, and such a picture is in all mechanical respects assured of an unchanging durability. If too much of the small amount of oil which is used disappears by oxidation, it can easily be replaced and the picture restored for a new series of decades.

These relations are all changed in a marked degree when the color is laid on thickly. Under these circumstances the solid product from the oil is formed only at the surface, the dense layer which is produced protecting the oil below against the entrance of air. When the outer layer contracts in the course of further oxidation the lowest layer is still soft and it therefore splits into small pieces. The same thing takes place when other colors are laid on over half-dried portions of the picture, where the change is going on with a different velocity. If you wish to get a good idea of all this, paint with pure Madder on a white ground. After a week or two you will find the coat of color traversed by numberless white lines which have been

produced by the contraction of the mass. Any picture gallery will give you opportunity for similar observations, especially on parts of pictures which have been painted with a bright red. Even in mixtures with other pigments Madder shows this tendency to crack when it is present in considerable quantity. A further cause for the production of cracks is a thick or otherwise improper preparation of the linen. It is usual to cover the linen first with several layers of a color made by mixing glue with chalk or clay, and often several layers of oil color are laid on over this. The thicker this ground and the greater the difference in the layers of color composing it, the greater the danger of a difference in expansion and the appearance of cracks.

It seems to me that the very general use of linen for oil painting is the result of one of the many prejudices from which art has to suffer nowadays. At a time when the manufacture of large sheets of paper or pasteboard could only be carried out by pasting together smaller sheets, great surfaces of linen were very welcome; but at the present time paper and pasteboard may be had of practically any dimensions, and these can be changed by a coat of glue or casein of the proper

strength into a ground which absorbs in any desired degree. There is therefore no real reason why pasteboard should not be used instead of linen, with its inconvenient frame. It is also possible to produce any desired grain by coating pasteboard with the proper kind of paper, and grounds can be produced in this way which meet all demands. It would be even better to glue linen to pasteboard instead of stretching it on frames, for it would then lose its dangerous property of changing its surface area greatly when it becomes moist. If this course of thought is carried out, it is not far to the idea of using metal in the form of sheets or foil as a ground for painting. Aluminium would seem to be an ideal material for this. Its light weight makes it easy to handle even for large pictures, and its chemical properties exclude the possibility of any dangerous action on the colors. It will depend on circumstances whether the colors should be laid directly on the rough surface of the metal or whether it would be better to give it a coat of paper or linen. The use of a metal as ground would certainly permit of the production of effects which are worth a more thorough study than I have yet had time to give the matter.

While one can in this way give any desired degree of durability to the ground, the question still remains whether it is possible to overcome the other disagreeable properties of oils, and this question can also be answered in the affirmative. The value of oil as a medium depends on the fact that the optical properties of the colors remain unchanged when the picture hardens, so that the artist is able to calculate the effect of color and light very accurately. It would be possible to attain the same result by separating the mechanical action of the oil as a medium from its optical effect as a transparent and strongly refractive substance connecting the granules of pigment, giving these two functions to two different substances. One solution of this problem could be reached by painting on a strongly absorbent ground. The larger part of the oil would sink into this ground and there would remain between the granules of pigment only enough to produce mechanical coherence. The optical result would be that the colors would *strike in* as a consequence of the entrance of air between the granules, — that is, much more light would be reflected from the surface and the picture would lose in depth and in color. If, now, the interstices are filled up again

with a strongly refractive substance, the original condition is restored and the picture brought out. This second function could be given to another substance which has not the property of turning brown or darkening as oil does. Such substances are the resins, mastic, dammar and sandarac, which are in common use in making varnishes. They are, to be sure, also subject to changes with time. They do not turn brown, but lose their transparency and become "blind." The illustrious Pettenkofer showed us how this evil is to be overcome, and he is the man whom we must thank for the first successful scientific treatment of the problem. A longer or shorter exposure to the vapor of alcohol or any other appropriate volatile solvent for the resin brings back transparency to the picture without the necessity of touching it at all.

In order that such a process may be completely successful, the varnish must not be applied until the oil has dried for a sufficient length of time to have become completely solidified. The picture must be painted wet and then allowed to dry for a long time, several months at least, before the varnish is put on. If one then writes on the back of the picture exactly what was used in painting

and varnishing it, the possibility is given of restoring, at any time in the future, the effect desired and obtained by the artist.

This is not the only way to reach the desired end. You may, for example, paint on a nonabsorbing ground with a pigment containing only sufficient oil to hold it together, producing the necessary fluidity of the colors by the addition of a liquid which afterward evaporates. Such a picture will "strike in" soon after the laying on of the color because of the disappearance of the volatile substance, but it can be brought out again by means of varnish. As diluents, the ordinary ones, especially oil of turpentine and oil of spike, are to be recommended. The latter is much the less volatile and leaves the picture wet for a correspondingly longer time.

If a picture which has struck in is to be brought out again for further painting, it is best to use the same volatile substance without any addition, putting it on with an atomizer instead of a brush. There is no cause for anxiety that too little of the binding substance will remain, especially if the oil has hardened somewhat, and in case of necessity there is no difficulty in laying on with the atomizer a coat consisting of a mixture of oil of turpentine

and poppy oil, thus producing any desired degree of coherence.

The artist will find in this discussion much that belongs to well-known methods. But an explanation of the reasons which have led to the choice of this or that process is always an aid not only in the application of what is known or what has been discovered but also in the further development of processes; and the danger of future creations being impaired by the introduction of undesirable properties is avoided.

XII

MY DEAR SIR:

You ask why the various colors dry with such different velocities even when they have been rubbed up with the same oil. The answer leads into one of the most interesting chapters of physical chemistry, and it will therefore be given at considerable length.

The oxidation process which leads to the hardening of linseed oil does not take place instantaneously when oil and air come in contact with each other, and there are numberless other chemical processes which go on quite slowly even when the conditions for the reaction, as far as the presence of the necessary substances is concerned, are fulfilled. The study of the time relations in such processes has become a definite division of science, called *chemical kinetics*, which has made great strides in the past decade.

One of the most remarkable things in chemical kinetics is the fact that the time which any process takes to reach a given stage depends not only on external conditions such as temperature

and pressure, and on the concentration of the reacting substances, but also in a very great measure on the presence of certain other substances which take no part in the resulting product and are not used up during the process. To give you an idea of this, let us say that they act like oil on the rusty bearings of a machine. Any piece of mechanism runs with far greater velocity, other things being equal, when the bearings are oiled, although the oil is not used up directly. Substances which have this peculiar property are called *catalyzers*, and the acceleration of a process by their aid is called *catalysis*. As a rule, a very minute amount of the catalyzer is sufficient to produce a very great acceleration of the process. There are usually special catalyzers for each reaction, and it is necessary to work out for each case just the substances which exert this remarkable influence.

It is a well-known fact that linseed oil dries very much more rapidly when it is used to rub up lead pigments (Flake White, etc.) than when it is used for Zinc White; and it can be given the power of drying rapidly under all circumstances by boiling it with any compound of lead. This fact exhibits the characteristic peculiarity

of a catalysis. Lead compounds accelerate the oxidation of linseed oil and make it "dry" faster. Linseed-oil varnish, which is merely a rapid-drying linseed oil, differs from the ordinary oil only in containing such catalyzing substances, and siccative, a substance added to linseed oil to make it dry rapidly, is a concentrated solution of such a catalyzer.

The power of accelerating the oxidation of linseed oil in a catalytic way belongs not only to lead compounds but also to those of manganese and probably also to similar substances derived from other metals. It seems probable, from the remarks in old books on painting, that verdigris, a compound of copper, may also have this same influence, but there has been too little research on this point for us to say anything very definite about it. Well-known recipes for the boiling of varnish make it probable that a catalyser is produced simply by long-continued boiling of linseed oil in contact with air; the oil acquires the property of drying rapidly merely by continued heating. Here again scientific investigation can take a hand, and modern physical chemistry is perfectly able to handle the study of catalytic phenomena.

From what has been said, you will readily understand the importance, which every conscientious teacher should feel, of warning scholars against the too lavish use of drying media. In my previous letter I explained the theory of the cracking of oil paintings. The most important point to be considered is the difference in time required for the oxidation of the superficial and the interior layers of the mass of color. The use of a siccativ has the effect of still further increasing this difference in time: the surface dries in a few hours and incloses the interior so firmly that it takes as long to harden as an ordinary color without siccativ. In both cases the solidification of the interior takes place only as fast as oxygen reaches it from without by diffusion, — that is, by the slow penetration of the external layer. The drying medium accelerates not only the first hardening of the oil, but it accelerates in apparently the same degree further undesirable changes in the hardened oil, especially shrinking and discoloration. The normal action which takes place in ordinary colors after a long time shows itself in a comparatively short time when siccativ is used, and begins the quicker the larger the amount of drying medium which has been added. A picture

which has been painted with a great deal of siccative is therefore an old man on the surface while it is still a youth within, and it does not require any long explanation to prove that such a combination is not a good one.

The use of a drying medium is not by any means so dangerous when the coat of color is kept thin, for the undesirable results just pictured naturally increase in rapid progression as the layer of color is thicker. If the coat is thin, the oil in it will become as hard in a few days as it would in months without the use of siccative; and if it is then varnished, further access of oxygen to the oil and the progress of undesirable changes in the hardened picture are practically brought to a standstill. I should have no hesitation in painting a picture which must be quickly finished with a thin coat of color and plenty of siccative, varnishing it after a few weeks' drying. Here again experience must speak the decisive word, and my intention is only to formulate a group of conditions which promise good results, basing it on our present knowledge. Such a process is especially convenient in working from nature. A colored drawing paper of rather heavy grain can be used as ground. This is prepared with a six

per cent gelatin solution; and if one uses ordinary oil colors, diluted with a medium made by mixing siccative with ten times its volume of oil of turpentine, no time is lost in technical difficulties, and a study can be carried a long way toward completion in an hour. The distances are put in with the thinnest color, almost as in aquarelle, and a proper choice in the color of the paper simplifies the work greatly. Large surfaces belonging to objects against the distance are left blank, while smaller ones are simply painted over. After a quarter of an hour's work in putting in the remaining masses, the color of the distance will be found to have hardened so firmly that details can be put in on it safely and neatly. By working always from below upward, objects in the foreground are involuntarily given the heaviest coat of color, and this insures their plastic appearance. I have sketches made in this way which are more than twenty years old, which have had no care whatever, and in which I cannot discover the slightest trace of change, though most of them were never even varnished. This I ascribe exclusively to the thin layer of color, for I did not think it worth while to take the other precautions for insuring durability in these vacation sketches.

I did, in fact, add some amber varnish (about one tenth) to my medium, to prevent the picture from sinking in and to avoid later varnishing. In this I sinned consciously against the conditions for greatest durability without any evil results so far as I can see. The effect may become visible after a few hundred years in case my scraps are still in existence.

And now, finally, a few words about pasty painting. If you investigate the optical effects which can be produced by its means, you will find but one,—a bright spot of light on the smooth surface of a drop of color. Rembrandt understood this application of plastic and used it in the finest and most intentional way. Otherwise the colors as they exist in the picture are usually made so opaque by their content of lead white that a layer a tenth of a millimeter thick prevents underlying colors from appearing at all. If a pure white ground is used, and this is advisable for all final work for the sake of added security, its complete covering is not only unnecessary but is often even a disadvantage. The coat of color can therefore be very thin and the white ground can be allowed to show through the paint as an aid to the production of livelier color effects. If the thick

coat is thoughtfully confined to certain small spots, all the causes of flaking and cracking are avoided. Judged from the standpoint of artistic effect, there is nothing in favor of laying paint on thickly over the whole picture, for the "signature" of the artist certainly need not be proportional to the amount of color per square foot. Besides all this, the numerous reflections which appear on the surface of a picture which is thickly and irregularly painted make it almost impossible to find a viewpoint where disturbing reflections do not appear, especially when artificial light is used. The only arguments in favor of this method can, it seems to me, be collected in the one word *fashionable*.

XIII

MY DEAR SIR:

You ask me to explain the basis for my remark that a white ground should be used for all final, serious work. You admit that the old Italian, Flemish, and German painters used it, and Böcklin as well, but say that you prefer a colored ground for many purposes.

In order to treat this important question thoroughly, I must first take up a problem which has so far been merely mentioned, — that is, *glaze*, in its special application to the technique of oils. As you know, a glaze consists of a transparent colored coating over a ground which may have any color whatever. A great increase in the effectiveness and depth of color can be attained by this means. Something has already been said (page 98) of the way in which these effects are produced, but we considered at that point only the effect of a white ground. Let us now examine how a glaze acts when laid over a colored ground, taking first the simple case where a transparent color, such as Madder Lake, is laid on over a body pigment

of the same general color, — English Red, for instance.

Many attempts have been made to give a name to the result which is obtained in this way. Such terms as "fiery," "brilliant," and "deep" are used. The effect is like that produced by the pure spectrum, where no white is present mixed with the other colors. Deeply colored stained glass gives the same effect for the same reason. When a transparent red is laid over an opaque one the effect depends on the following facts. The opaque color below reflects principally red light, with which is mingled some white from the surface. This white light is then colored red by the transparent glaze, so that only red light remains, and this is the reason for the purity, brilliance, and depth of the resulting color. Other colors beside red can, of course, be used in the same way to produce a similar effect. The process is somewhat more complicated in its nature when a glaze is laid over an underpainting of a different color. Since the transparent color acts on transmitted light, it has the property of removing certain colors from the light which enters it. These are complementary to the color which the pigment exhibits. Madder Lake absorbs principally green,

Prussian Blue principally reddish yellow, etc. This whole point becomes clear if one turns a pocket spectroscope on a source of white light (a white cloud, for example) and then brings a piece of glass covered with the color in question in front of the slit. The opaque pigments act by reflecting the color in which they appear and absorbing the complementary color. It is now easy to get an idea of the whole effect. The transparent glaze permits only certain wave lengths, that is certain colors, to pass, and only a part of these are reflected by the opaque pigment below, the reflected part being acted upon a second time by the transparent color in the same way as before. The result is that only a comparatively limited range of colored light emerges, in which no white is present.

If undercolor and glaze are chosen close together in the spectrum (as orange and red, yellow and green, etc.), comparatively more light of greater purity of color is reflected, and the result is "brilliance of color." Good effects may be successfully produced by this method in the case of objects like transparent water, brightly colored stained-glass windows, sunlight shining through leaves, and the like, where no surface light appears.

If undercolor and glaze are chosen further apart in the series of colors, the quantity of reflected light is smaller and the result is a darkening of color.

By laying on over an opaque ground a complementary transparent color as pure as possible, a very deep yet colored effect can be produced. The blackest black is obtained by laying alternately on a black ground transparent complementary colors, — Burnt Sienna and Prussian Blue or Indigo, for example.

The question as to what determines the difference in the properties of transparent and opaque pigments is to be answered by the application of the principles explained in the case of reflection, and they are identical with those used already in explaining other effects. As was there made clear, that pigment covers best which has a high index of refraction, and, vice versa, that one covers least which has a small index of refraction, or more exactly, one equal to that of the medium surrounding it. The transparent colors are examples of the latter case. Since no pigment has an index of refraction as small as that of air, there can be no possibility of producing glaze effects in a process where the pigment granules are largely

surrounded by air. This is especially true of pastel, and sets the most important limitation to the powers of this process. Of course many pigments take on a transparent character when they are used with a medium of high refractive power. Since resins and drying oils are far ahead of gums, gelatin, and white of egg in this respect, it is evident that this effect must find its largest and most successful field in work with oils. It will also be true that the best transparent pigments will be such as are not merely mechanical suspensions but real solutions. This property is evident in the case where metallic oxides are dissolved in glass, and the result is transparency combined with great depth and richness of color.

In the ordinary processes of painting true solutions of pigments are of almost no importance. All substances which form true solutions show also the property of *diffusion*, — that is, they spread out into neighboring parts of the solvent where they were not present before.

Such diffusion is also possible in apparently solid media like dry gelatin, gums, and resins, though it takes place much more slowly in such media than in fluid solvents. The result is that a diffusion ring forms about each spot of dissolved

color, which takes on the form of a shaded disk, and extends out into the solvent. You can get a very good idea of this from blue designs on glazed porcelain (in the Meissen "onion pattern," for instance), for they always show this smudgy edge to the lines of the drawing. The reason for this is that the blue cobalt color is on the porcelain when it is exposed to the highest temperature, at which the glaze is in a semifluid condition. The dissolved cobalt oxide, which forms the blue color, diffuses into free parts of the glaze from the places where it was originally placed, and forms this characteristic diffusion edge to each line of the pattern. Sharp drawing is destroyed when this action takes place, and one must therefore avoid the use of dissolved pigments in real painting.

The only pigment which requires mention here is Asphaltum, and the fine effect of this substance in glaze is due to its being in solution. The phenomena just described are inseparable from it, however, and careless use of this pigment leads to unexpected and undesired effects, which may sometimes be disastrous.

Colloidal pigments are free from diffusion, a bad property of dissolved substances, and they have, besides, optical properties which are almost

without fault. This name is given to noncrystalline substances, which do not form real solutions, but which combine with solvents to form suspensions having many of the properties of solutions.

They can be diluted with any desired amount of the solvent, and show a transparency nearly but not quite as great as that of true solutions. The difference in this point is shown by the fact that while such solutions often seem quite clear by transmitted light, they show a dispersion of light by reflection. A good example of this is a solution of Prussian Blue in a great deal of water. This looks quite transparent by transmitted light, but when a cone of sunlight is formed in the liquid by a condensing lens it shows a copper-red color, and the same color may be produced by rubbing the solid pigment with a hard, smooth implement.

The lakes are the most common of the colloidal pigments. They are compounds of organic coloring matter with aluminum hydroxide or alumina. In earlier times there were only a few naturally occurring organic colors, like carmine and madder, which were used to prepare lakes, but nowadays numberless artificial colors of all

hues are prepared commercially, and the list of lakes has become a very extended one. Fortunately it is only occasionally that these usually rather unstable products get into colors intended for genuine art painting, and most of them are used in the wall-paper factories.

Madder Lake is far superior to Carmine Lake in the matter of durability. There is no difference whatever, either chemically or physically, between the artificial alizarin pigment and the natural madder color, except that the artificial color is purer and therefore probably more durable than the natural one.

The organic colors are about the only ones which are well adapted to forming lakes with alumina, and since they have often only very slight durability, whether natural or artificial, it is usually supposed that the lakes as a class are not "fast" colors. But manufacturers of colors have learned how to make a series of remarkably fast artificial colors, which are not only able to replace the old ephemeral ones but which are also much better in every way. They cannot be distinguished from the others at a glance, however, and until the artist has learned to test colors of unknown properties with respect to their

stability in light he should not admit them to his palette. But the great firms of acknowledged integrity who furnish the painter his pigments should undertake this work of testing out colors, so that they may offer the artist trustworthy lakes.

Some pigments are also included in the class of glaze colors, which are neither real nor colloidal solutions, such as the Sienna earths, Umber, etc. These acquire their transparency, when mixed with the medium, by virtue of their very low refractive power, which is about that of the oily and resinous media. Total reflection and the cloudiness of the medium are at a minimum under these conditions, but these colors are by no means as perfectly transparent as are the true and colloidal solutions. They therefore form the first step in the transition to the opaque colors, which are at the other end of a series of pigments of increasing refractive power.

XIV

MY DEAR SIR:

Indeed, I have not forgotten the question about the ground on which to paint, but I did not want to take it up in my last letter because the explanation of the effect of transparent colors had already reached sufficient length. To-day I shall try to defend my previous assertion.

The painter usually tries to reproduce on his canvas an effect as closely like that of the natural subject as possible, or one which recalls this clearly. He finds a fundamental difficulty in his way, for the range of light which he has at his command is incomparably less in extent than that in nature. The picture is viewed in a room by a medium light, and the whitest Flake White cannot reflect more light than falls on it, so that this comparatively weak light is the brightest which the painter can use to represent the subject he is reproducing. Nor is it possible to extend the series in the other direction, for the blackest black on the palette cannot be darker than a place in the subject where there is no light, — an opening

into a cellar or cave, for example. Such a spot is always lighter in the painting than in nature because of unavoidable surface reflection.

There is, then, every reason for being economical with the means at hand if one expects to get striking results in light and color in a picture. If these are not desired and if the abstract effect of drawing is the aim in view, this reason for choosing a white ground no longer exists, though such a ground might be used even in this case.

Suppose you wish to produce a very pure and fiery red in your picture,—a stained-glass window with sunlight streaming through it. This can be best attained by laying yellow and red glaze colors alternately on a white ground until surface light is all cut out and only red body light remains. The amount of light that can come from this spot depends largely on the reflecting power of the ground, and it follows immediately that you will get the most light from a white ground. It is also evident that for effects like this a chalk ground will not be so good as a ground of a more refractive white,—Flake White, for example; for if the medium used with the transparent color is absorbed by the ground at all, the reflection will be less when its refractive power is small. There

is an easy way of avoiding this difficulty. If the ground is of such a nature as to prevent the absorption of the medium, the latter cannot produce any darkening effect, and the desired aim is reached even with a color of low refracting power.

This is the reason why the glue and plaster-of-Paris ground, which was used by the wall painters, gave such good results, and this is the ground to which Böcklin finally returned. Plaster is a substance of not very high refractive index (1.5 to 1.6, or about the same as chalk), and it is therefore made rather transparent by oils or varnishes; but when it is mixed with glue the oil cannot get into it and the reflecting power of the surface is unchanged.

It is precisely by the use of these principles that these old painters gained their marvelous depth and splendor of color. It has been often maintained that this is unattainable for ordinary mortals, but this is only true of such as do not understand the necessary optical conditions, or the means of attaining them.

I am perfectly sure that with the aid of the simple recipe — a color as transparent as possible on a ground as white as possible — optical effects as good and even better than those produced by

these old masters can be attained. If you wish to convince yourself, fasten an ordinary sheet of colored gelatin, such as is used for all sorts of purposes, to pure white paper or some other good white ground and try to imitate the effect with an opaque color. You will not succeed, simply because you cannot exclude surface light in the case of the opaque color, while it is excluded in the case of the gelatin. But you will succeed if you use a transparent color, because the colored gelatin is optically nothing more nor less than a glaze.

The modern painter does not very often have occasion to produce an effect of this kind. It is perfectly evident that in a naturalistic picture such means should only be used where the natural subject shows body light without surface light. The old painters were trying to give to their saints and madonnas draperies as beautiful in color as they could possibly make them, without considering particularly whether these draperies looked like any real materials. Nowadays surface light is the important thing in a picture. The extensive pollution of the atmosphere in modern cities has called the attention of every one, the painters in particular, to the optical effects of

foggy air, and the æsthetic art literature of to-day is full of cloudy phrases, "the light which floods all bodies," and things of that sort. As a matter of fact, the light which is passing through a colorless, transparent medium like air is wholly invisible to us and neither can be nor needs to be painted. It is the particles of soot and dust in the air which are really visible, and these diffuse in all directions the light which falls upon them, producing in this way a gray or blue effect, which increases as the active layer becomes thicker. In this way the darkest parts of objects are lightened more and more into blue or gray as they are more and more distant from the observer. These effects have been known for hundreds of years and are expressed more or less happily in the term "atmospheric perspective."

They appear at less and less distance as the air is dustier, and there is, in fact, much more atmospheric light to be seen and painted nowadays than there was in former centuries. In New York the black objects on the other side of the street show, on careful observation, perfectly evident atmospheric light, while at the seashore I have often seen objects in their own colors at a distance of several kilometers, with just the

faintest trace of atmospheric light over them. If care is taken that the color is shaded off lighter with increasing distance, and if this is carried out even for fairly short distances, no difficulty will be found in producing the effect of a "flood of light." All this atmospheric light is surface light, and it is perfectly clear that opaque colors and not transparent ones must be used to produce the desired effect. Such an effect can be produced in the finest and most natural way with the aid of a milky glaze of very thin white color, but this process is not without its technical difficulties. Here we have a case where a white of low refractive power is better than one with larger; for, to produce the same effect, the coat of white can be thicker as the refraction of the pigment and that of the medium approach one another. Experienced painters use in this case the less refractive Zinc White instead of Flake White, for the technical difficulties are much less as the coat of color is thicker, and extremely thin layers must be used to produce the desired effect. It would therefore be advisable to go still further down the scale of refractive power for this "atmosphere white" and to use plaster or pure precipitated chalk for this purpose. The presence of a small amount of

iron very often makes ordinary chalk too yellow to be useful.

By thus taking the atmospheric light into account, the painter has shortened his range toward the black end still more, for he must stop at a deeply shaded gray if this effect is not to be spoiled. He has therefore a lively interest in keeping his range as great as possible toward the other end, — that is, in keeping his white as bright and unsullied as possible. This is most easily attained by working on a white ground, for under these conditions he is not obliged to put on thick coats of Flake White where he wants the greatest brightness. A lack of consideration for these points explains why air and clouds, in the pictures of many painters of atmosphere, seem so heavy and massive, — as though they were made of thick clay. These heavy coats are not necessary if a white ground is used.

Böcklin's pictures present a fine opportunity for study here. He painted transparent things, air and water especially, with transparent colors on a white ground. This same technical method was used to get translucent marble and wet stone; but wherever he had occasion to use atmospheric light you will find opaque colors. I do not wish

to assert that this is systematically carried out. In his later work his rocks especially sometimes seem too intangible because of the lavish use of transparent colors.

Most of these ideas were expressed by Ludwig, who combined them with his unfortunate petroleum process and his no less unfortunate one-sidedness as an art critic.

I must close. If we follow these considerations any further, we shall be getting into the psychophysical part of the question, which we will keep for a later time.

XV

MY DEAR SIR:

One more technical process remains to be especially discussed, namely *tempera*. There is no such sharp boundary here as exists in the processes we have already considered, for the word "tempera" meant originally *any* medium for color, and even now the most various mixtures are so named. It is here especially that modern color alchemy and quackery show their most perfect bloom and bear their worst fruit.

At the present time we understand by *tempera* those media which can be diluted to any degree with water while they are in the fresh state, but which become insoluble in water when once dry, or after standing in the air for a time. The technical advantage given by such a medium lies in the possibility of painting over colors already laid on without any danger of disturbing them.

Chemistry offers a whole series of means for solving this problem. The principle of the oil process might be used, and a substance chosen which becomes insoluble by oxidation; or the

action of light in making certain combinations of substances insoluble might be used; or one might apply to the finished painting a substance which will make the medium insoluble. My chemical imagination is exhausted for the time being, but I think I could give you a few more ideas by trying a little harder.

To show you how these generalities can be changed into definite recipes, I will give you an example of each of these cases. The first case would be represented by a mixture of gelatin with ferrous sulphate. The iron salt is changed in contact with air to a higher state of oxidation, and a compound results which makes the gelatin insoluble. This tempera is unfortunately rather brown, so that it is not adapted for use with all colors. Or one might paint with gelatin to which is added a very small amount of any soluble chromate. The action of light is then sufficient to produce an insoluble compound from the salt and the gelatin. Here also the yellow color of the chromium compound is somewhat inconvenient, but this disappears under the influence of light, being replaced by a more neutral tint. Finally, you might paint with gelatin, and spray with a solution of formalin after each coat is dry. This

combines with the gelatin to form an insoluble compound, and the desired end is attained, for the excess of formalin evaporates, escaping without any further effect on the picture.

I have given you one example of each case, but I could increase this number considerably if I were not afraid of giving you a "chemical scare." We will leave the matter here; but I will first call attention to an important means, already much in use, which is capable of infinite variation,— the use of emulsions.

An *emulsion* is a mixture of an aqueous liquid with globules of another liquid which is insoluble in water, as oil or fat. Milk is an emulsion, in which the butter fat floats about in the form of very small globules which do not easily unite to form larger masses. Churning does unite them, but you know that this is not very easy for an inexperienced hand. Yolk of egg is an emulsion, which consists of a yellow oil suspended in albumen in the form of minute drops.

The great value which such mixtures have in tempera work is evident if one considers the properties of a well-chosen example, for instance casein in linseed-oil varnish. If a pigment is rubbed up with this mixture, it may be diluted to any degree

with water, and can therefore be applied like aquarelle or wash. On drying, the first effect is the hardening of the casein. At the same time oxidation of the linseed oil begins; this also hardens, and the acid produced during this oxidation makes the casein insoluble.

The pigment granules are therefore doubly bound and by a medium which has especial toughness because of its peculiar reticulated structure.

On account of these advantages modern tempera is usually carried out with emulsions. Such a medium requires a substance soluble in water and possessed of rather sticky properties. Gum arabic, gelatin, albumen, casein, etc., may be used. One must also have either an oil, or a liquid resin with the necessary properties, and here the drying oils (linseed, poppy, and nut) and the liquid resins and varnishes (turpentine, copaiba, Canada balsam, and oily amber or copal varnish) may be used.

The first constituent is dissolved in water to a sticky mass of the consistency of oil, and it is then mixed with a fifth to a tenth of its bulk of the constituent chosen from the second series. After a quarter of an hour's trituration the two combine to a creamlike, nontransparent mixture, which

possesses the desired properties and will dry as a transparent medium.

Yolk of egg is the usual aqueous constituent, but it is not the best, because it contains an oil which does not dry well and also because of its yellow color. Albumen is better, and casein, dissolved in alkali, better still. In the last period of his work Böcklin used a solution of cherry gum in which a ninth part each of kerosene, balsam copaiba, and turpentine were emulsified. The only objection to this would be that the kerosene might be superfluous, but it may have an effect which cannot be foreseen.

The technical importance of tempera lies in the fact that the separation of the optical and the mechanical duties of the binding medium, which was spoken of in the last letter, is here systematically carried out. A color is laid on in tempera, and brought out, after drying, by means of a varnish. There is, then, no difficulty in going on with further work, and varnishing again. Moreover oils, especially the transparent colors, can be laid on over a substratum of tempera. E. Berger thinks it very probable that the beautiful color of the old Flemish pictures depends on the use of some such process, — oils laid on over tempera. A good

tempera medium dries out and hardens through the entire mass of the picture by virtue of its peculiar properties, and so the cause of cracking, which was explained in connection with oils, no longer exists. Even the addition of a transparent layer of oil color above the tempera does not introduce this danger, for such a coat is naturally very thin. To be sure, we are assuming that trouble is not introduced by the ground, and to avoid the danger of cracking from this cause tempera as thin as possible should also be used for the ground. Barium sulphate rubbed up with a dilute tempera medium and laid on very thin makes an excellent ground for this purpose and for pastel as well.

Well, sir, we have reached the end of our wanderings. For the time being you must be content, as Moses was, to see the land of trustworthy processes spread out before you. I cannot lead you into it by means of any recipes of proved value, for my own experience is not yet ripe enough for that. But I hope that I have made the problems to be met and the means for their solution sufficiently clear to the artist who is willing to experiment. We have shown him the scientific fundamentals which will serve to give

definite direction to his efforts and aid him to avoid the usual attempt to reach the goal by lucky guesswork.

It is evident that no single solution of the tempera problem is the only possible one. It is possible to arrange a number of combinations all of which would have equal advantages. So much the better, for that leaves plenty of room for the individuality of the artist. I hope to have done at least one thing, and that is to have made it clear that an artist should not pin his faith wholly to concoctions with fantastic names, which are offered to him as tempera colors without any explanation of their composition. Let him make it an invariable rule to find out what the medium is.

XVI

MY DEAR SIR:

It is doubtless true that even with imperfect means pictures can be made which represent quite accurately the effect of light and of atmosphere, — for example, in a landscape. I must, however, reply in the negative to your query whether all this bother about improvement in technical methods is not superfluous. A sufficient answer is given by the very fact that most of the great painters, and especially those who understood how to reproduce important optical effects in their paintings, put a great deal of thought and labor into the study of technical improvements. And it is certainly true in general that when a man can do good work with poor tools he can do correspondingly better with improved ones. Of course the improved methods do not lead to beautiful artistic results in every one's hands, but only where they are properly applied. The painter has every reason to learn all that is possible about the results which he can obtain with his tools, for, as I have already

explained, the range of light and shade in nature is far greater than that which the painter has at his disposal. The problem of painting brilliant light effects looks at first glance like a quite hopeless one; but if you study certain pictures which have been painted with skill and knowledge, and with an effect of this kind always in view, you will be astonished at the blinding brilliance which the painter can attain with his weak range of light.

There hangs in the brightest part of my study a landscape by Jespersen, showing the sun setting over a meadow. The sun is low on the horizon, undimmed by clouds, but there are scattered clouds in the sky. Looking at this picture one has the sensation of blinding light, similar to that produced by the real sun under the same circumstances, when one can barely look at it. The sun is not even painted in brightest white, but is in fact yellow, and closer examination shows a violet spot in its center. There is not a pasty spot on the picture. With such moderate means the effect of the incomparably greater differences of intensity in the real sunset has been produced.

Analysis of the means used shows the following peculiarities: the meadow and the sky are much brighter near the sun than anywhere else: just

below the sun the horizon is nearly as bright as the sky or the sun itself. The real phenomenon produces the same impression, which is due to *irradiation*, an optical peculiarity of our eyes because of which any bright region seems to spread out into the neighboring darker regions, reaching farther as the difference in brightness is greater. In this picture the difference is very great and the painter has made his zone of irradiation correspondingly wide. It may be here objected that the irradiation in the picture should be produced by the same means as in nature, that is by placing light and dark regions side by side. But the painter would feel his narrow range if he were confined to the difference between his extremes in the way of pigments; for his whitest white placed beside his blackest black produces only a very slight irradiation, wholly incomparable with that of the sun against the horizon. This painter attained the desired result by giving to the effect, which is in fact a *subjective* one existing only in the eye of the observer, *objective* existence in his picture. By producing in the eye a condition similar to that which would result from a real irradiation, there is produced in the mind of the observer the sensation of dazzling brightness

which is the cause of irradiation in reality. A principle of enormous importance has been indicated here, — one capable of the most manifold application and consciously or unconsciously in continual use by artists: *Paint the subjective phenomena produced by the light effect into your picture, and you will give the impression which the objective cause would give if it were present.* Other applications of the same principle are to be seen in this same picture. The reddish spot in the center of the sun represents the fact that the center of our field of vision is a little less sensitive than the outer part. This fact does not appear in the ordinary use of the eye, but becomes evident when a dazzling light is received. The painter accordingly put this spot only in the center of the sun.

The most subtle touch of all is this. When one has looked at the sun an *after-image* is retained for some time by the eye, which dies away through a series of comparatively bright colors. This after-image is produced by a change in the retina of the eye at the point where the dazzling light is brought to a focus. It therefore persists and is visible wherever the eye is turned, — it moves with the eye. Now the painter has

put in these colored after-images at various points on his picture, and he has been so careful about it that one does not perceive these colored spots as such except on close examination. Therefore the unprepared observer does not notice that the painter has put these after-images into the picture. His eye receives the impression of an after-image of the sun no matter at what part of the picture he is looking, and it persists when he turns his glance to another place in the picture. He therefore has the impression that it moves with his eye just as a real after-image would. He is accustomed to receive such an impression only when the eye is dazzled by great differences in light intensity, and the impression that such differences are present is the result.

It should be remembered that the dazzling effect of this picture is greatest for the observer who is unprepared for it. It disappears somewhat when one has studied the means of producing it; and since I have often done this, the impression has become to me less powerful than it was at first. This is a very natural and unavoidable result, and it throws much light on certain historically well-founded facts which are hard to understand without its aid. As long as the observer is

acquainted only with such after-images as are produced by an objective dazzling light, *painted* after-images, about which he knows nothing, are remarkably convincing, since they suggest a real, dazzling effect. But after he has learned that painted after-images also exist, his conclusion that real after-images caused the effect is weakened and the effect is decreased. This great power of irresistible suggestion is given to every painter who is the first to discover and use such an imitation of nature. The effect of the suggestion is great on the observer who does not understand the conditions, and it is greater as the new effect is different from familiar ones. The later observer, who is already familiar with the new thing because it has been often used, is not so sensitive to the power of the suggestion.

This explains the enthusiastic reports of ancient times regarding the remarkably natural effects attained by painters of those days. From what we know of those paintings, they were in all probability very beautiful in other ways, but we probably should not consider them remarkable for their naturalistic qualities. Not very long ago a friend asked me how it was possible to explain the contemporary conviction of

the wonderful naturalness of Giotto's landscapes, for these pictures are seen at a glance to be childishly helpless in their conception and manner. The answer is simply that his contemporaries were not accustomed to compare the sense impressions of real nature with their representations produced by art, and that the approach to naturalness which Giotto was the first to make produced a suggestive influence at that time which is comparable to the effect produced by the sharp-sighted Jespersen on the modern observer.

The explanation which I have given you for the dazzling effect of this picture is of course equally applicable in general to all the subjective effects produced in the eye by light. To mention another example, and at the same time show you the remarkable breadth and value of this principle, I will take the case of the "spotted sky." For a number of years I have been bothered by a stupid fashion of painting the sky, which consists of putting in coarse bluish and reddish stripes criss-crossed beside each other. Inasmuch as I had never seen a sky like that, I took it for a very widespread and very foolish fashion until I finally came across a picture where the principle

involved was carried out correctly, — not simply used mechanically and in a superficial way. In this picture the two colors, a greenish blue and a reddish violet, were so carefully adjusted that their value was equal, and it was therefore difficult to recognize the boundary between them. Looking at a surface treated in this way, one cannot decide which color to focus the eye upon, for since the eye is not perfectly achromatic it needs a different adjustment for different colors. Just such an uncertainty is present when one is looking up into the clear sky with no object in its blue depths, having a definite distance on which the eye can be focused. Hence the effect of depth so evident in this painted sky.

These considerations open the way into a new division of the technique of painting, for we are no longer studying the materials as such but the way to produce certain effects by their proper use. To be sure this new subject is connected with the other by a perfectly continuous series of steps, for pigment and medium, covering power and glaze, are all merely means of producing on the canvas effects which shall appear to the eye of the observer like the natural scene.

The only difference lies in the increasing complexity and manifoldness of the phenomena. So far we have dealt with colors alone without regard to their points of contact and mutual optical effect. We must include the correspondences and differences of these colors as compared with the natural object, and their effect on the eye.

XVII

MY DEAR SIR:

You seem to be satisfied with the ideas and suggestions which you got from my last letter, but state with evident resentment that no iota of all this was taught or explained to you at the academy, and that you might have spared yourself much lost labor and many hard knocks if you had known earlier some of these general considerations which are so easily applicable to special cases.

I know nothing from personal experience about how things are done in the art schools, but I must say that many artists who have afterward won names for themselves have not had anything very favorable to say about their studies at the academy. This is in remarkable opposition to the fact that scholars very often remember their teachers at the university with gratitude, and frequently declare that the best things they have done were due to the training or at least to the suggestions received during their academic years. The capacity for independent scientific investigation seems to me just as great a thing as the capacity

for independent artistic work. If the first of these can be cultivated successfully by an institution, in a way satisfactory to the scholar, I believe the other can be also; that is to say, I think it is possible to make the instruction given in an academy of art as useful and inspiring as scientific instruction now is. If this goal is not attained, the fault must lie either in the method of teaching or in the matter taught; for in the art school as well as in the university instruction is given by men who have given proof of their creative ability in their own work.

One group of subjects which I regard as absolutely necessary for sound artistic work is either omitted from the work in the art school or else treated with slight enthusiasm. This is natural science. Anatomy on the one hand and geometry and perspective on the other are taught, but without very brilliant success, as may be seen by taking an hour's stroll through any exhibition of new paintings. Errors in perspective are, let us say, not very rare. Physics, especially optics, the physiology of vision, and psychology do not appear to be included in the curriculum. A shy beginning has been lately made in chemistry, in the interest of the technical side of painting.

I have no hesitation in expressing the following heresy: A good artist must have at least as thorough scientific training as a physician; he may leave out much of the usual work in æsthetics, which the lecturer often understands as little as the auditors. Other things which seem to me just as necessary I will not mention now, for we want to have the reform within the limits of present possibility.

You will ask where the student is to find time for all this. The answer is that a rational scientific education—one that goes straight to the point, however elementary it may be—will facilitate the technique of his art immeasurably. Things which he must otherwise learn by heart, uncomprehended rules in the use of which he must always stop to think whether he should not do just the opposite thing, need be said only once and he will incorporate them with his rational knowledge as an application of a general law which he already knows. When one sees, as I do continually, how rapidly the application of a general law becomes the student's habit of thought, there comes unlimited confidence in this method of teaching. And when the art student finds that what he learns immediately facilitates his work,

he will strive to acquire knowledge of this kind just as the young scientist does.

There I go! The teacher part of me is cropping out again. Let us return to the psychophysical side of painting, for I want to call your attention to a very important general relation. I will state it as strikingly as possible for the sake of emphasis:

If an artist is to reproduce nature in paint, he must learn how to see.

This is necessary because we do not see things as they appear optically to the eye but as we know them best. We do not ordinarily use our eyes to receive as colored spots the various colors and light sensations which come to us from the outer world, but we use them as a means of orienting ourselves in the world for everyday practical needs. For example, we see ordinarily nothing whatever of the oblique angles which the houses present to us as a result of perspective differences. We think of these angles as right angles, subtracting the familiar effect of perspective from the real visual image and constructing a right-angled house in this way. This shows itself when a child or an uneducated

person begins to draw. He puts square corners on everything which he knows by experience to have right angles, in spite of the fact that they give oblique angles in the visual image. The same is true of the perspective diminution of distant objects. All the mistakes which an inexperienced hand makes in this respect are in one direction, — he always shows less diminution in his perspective than really belongs there. Giotto, for instance, knew nothing of perspective and had only an idea that distant objects appeared smaller. His continual errors consisted in making the diminution in the distance too slight.

The same is true of colors. The color of an object is practically only of interest as an aid to its recognition. We accordingly subtract from every visual image the familiar special effect of the illumination at the time of the observation, and turn our whole attention to recognizing the true color of the object, its so-called "local color." The influence of this habit can be followed far into the so-called great period of Italian painting. You will find that in every picture all the objects are represented as though illuminated with perfectly colorless light. Even in cases where the difference is so evident that it could not escape observation,

as in the blue of the distance, it is treated as a local color, and almost no expression is given to the various conditions which always modify this distant blue.

I might add many more examples, but you will be able to add them more easily and in greater variety from your own experience. I will merely draw one general conclusion and use it in the formulation of a correspondingly general rule, the basis for all artistic work which has as its object the representation of natural phenomena: *The artist must continually force his eyes and his consciousness to lay aside the habit of the mental transformation of visual impressions*, so necessary for the practical side of everyday life. *He must train himself to see only patches of color* without regard to what they really represent.

In proportion to his success in leaving out this "reality" he will gain in the power of putting into his pictures the impression of reality and truth; for what he has to do is to bring about the optical condition in the mind of the observer which would be produced by the object itself, standing on the spot where it is represented. The observer takes care of the practical "translation," and precisely the fact that he has to attend to